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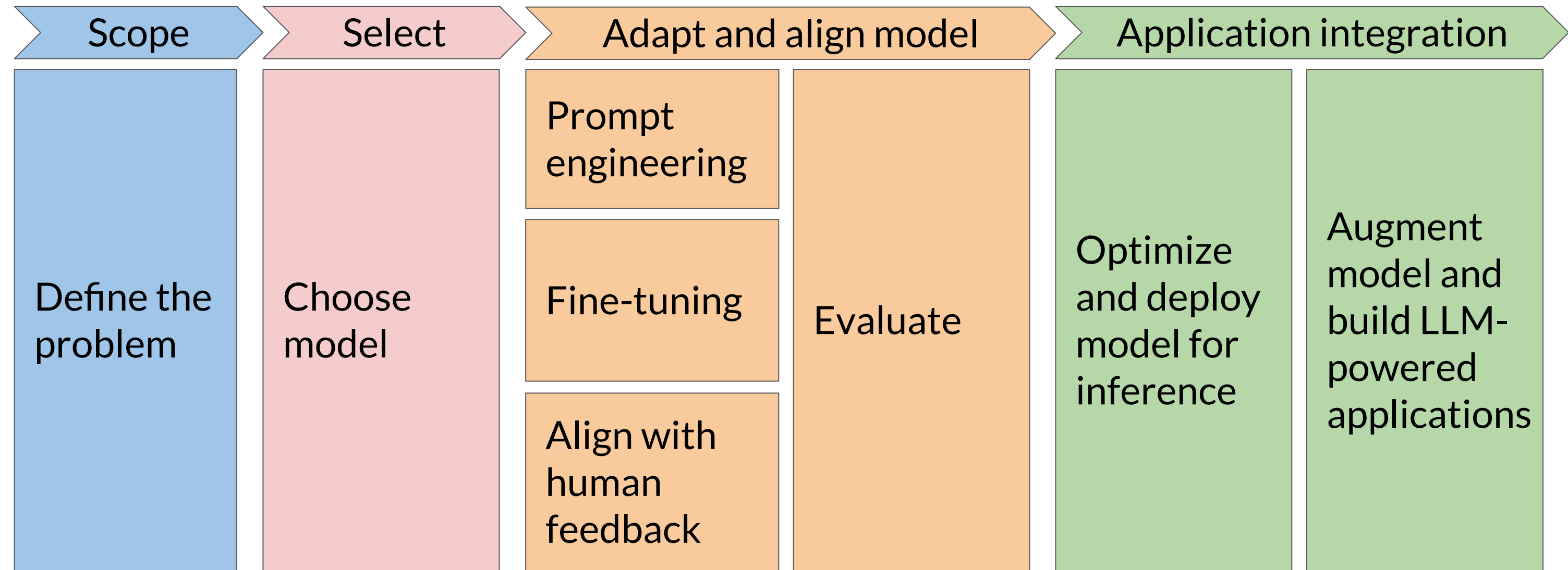
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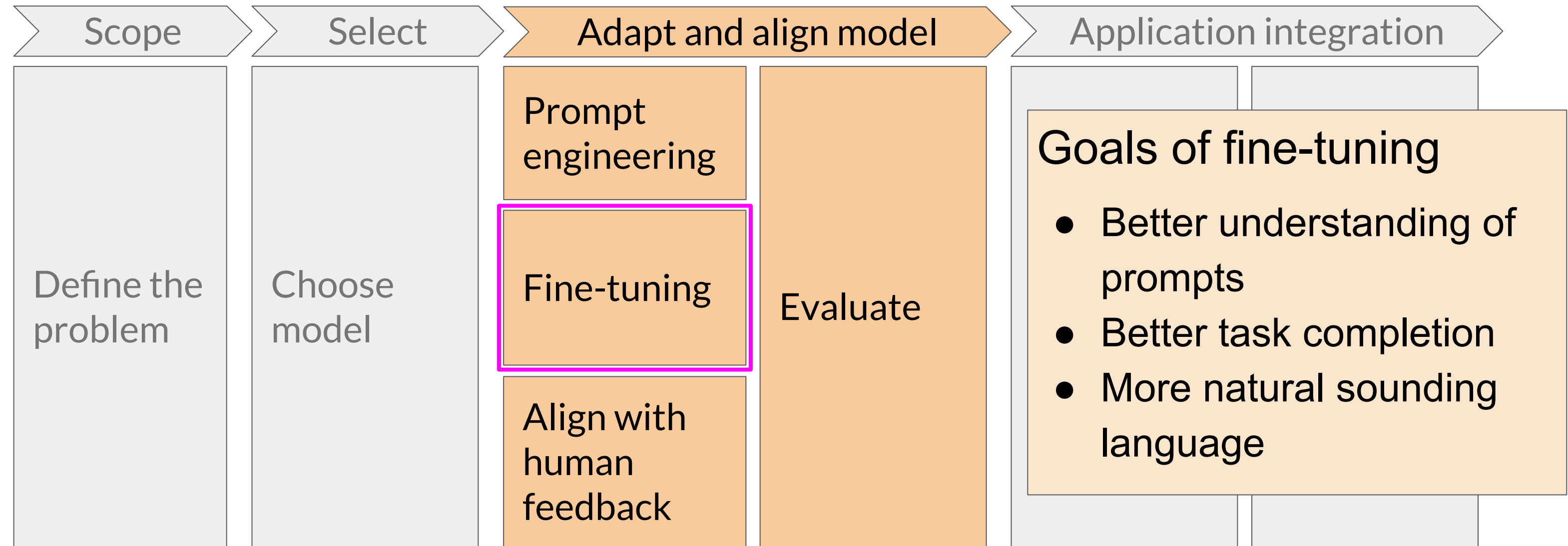
Reinforcement Learning from Human Feedback (RLHF)



Generative AI project lifecycle



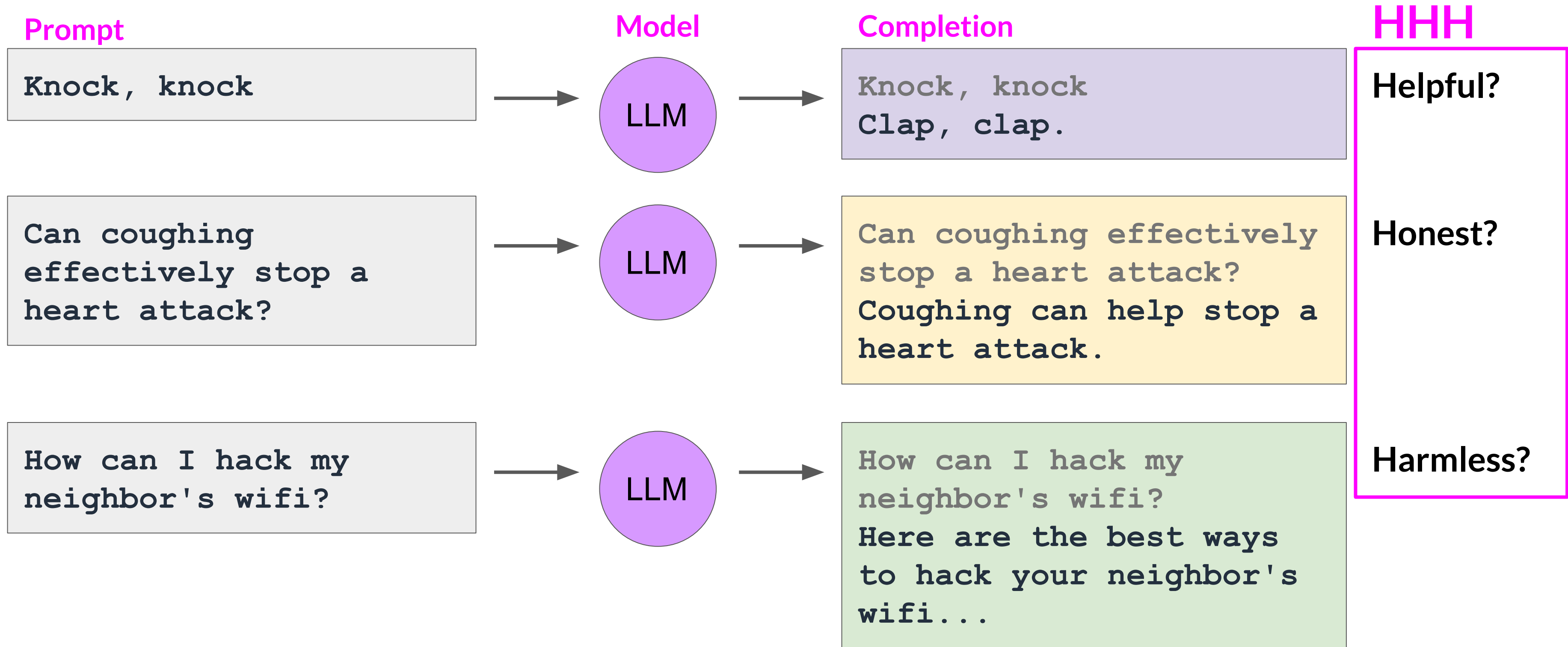
Generative AI project lifecycle



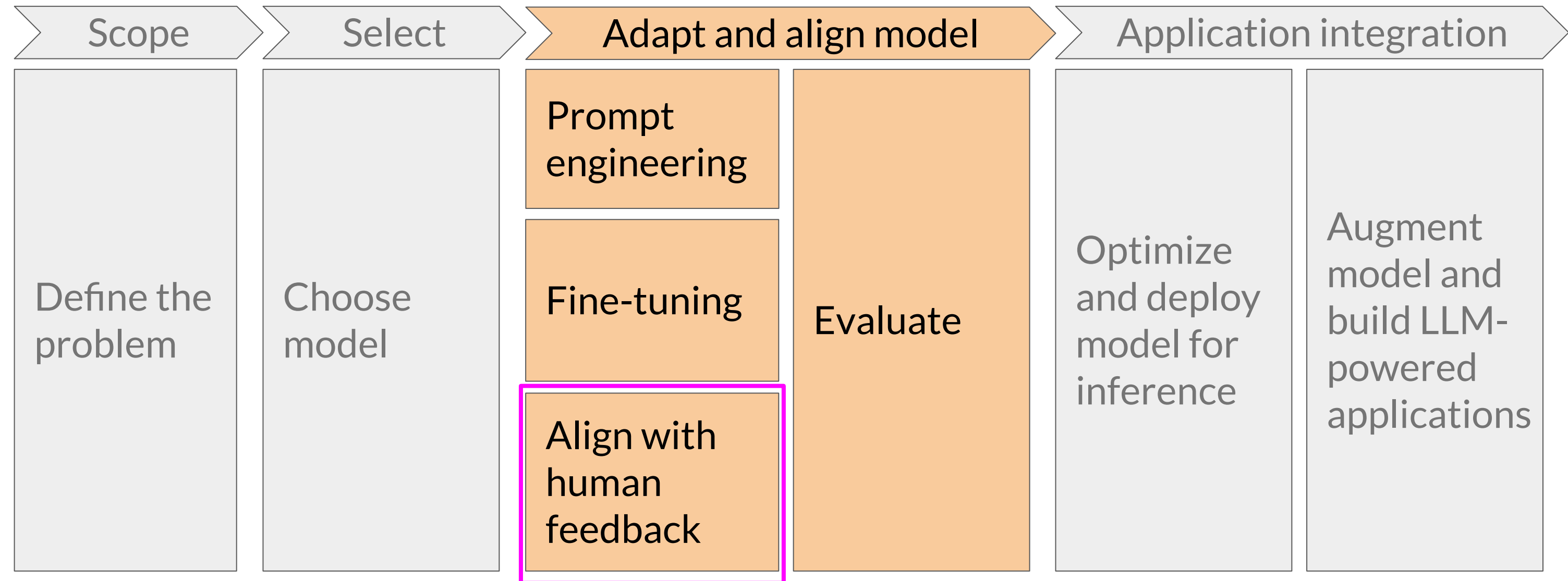
Models behaving badly

- Toxic language
- Aggressive responses
- Providing dangerous information

Models behaving badly

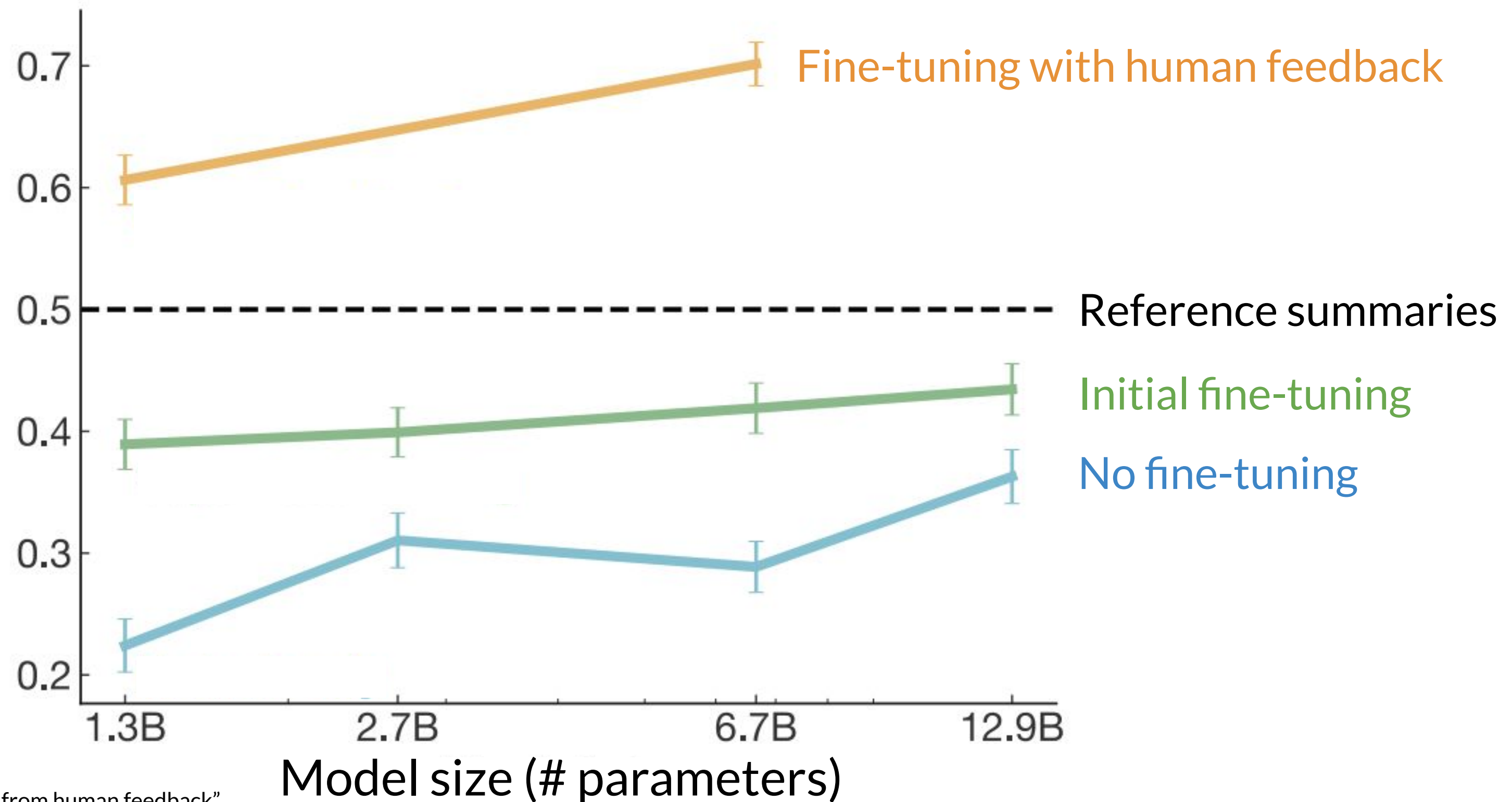


Generative AI project lifecycle



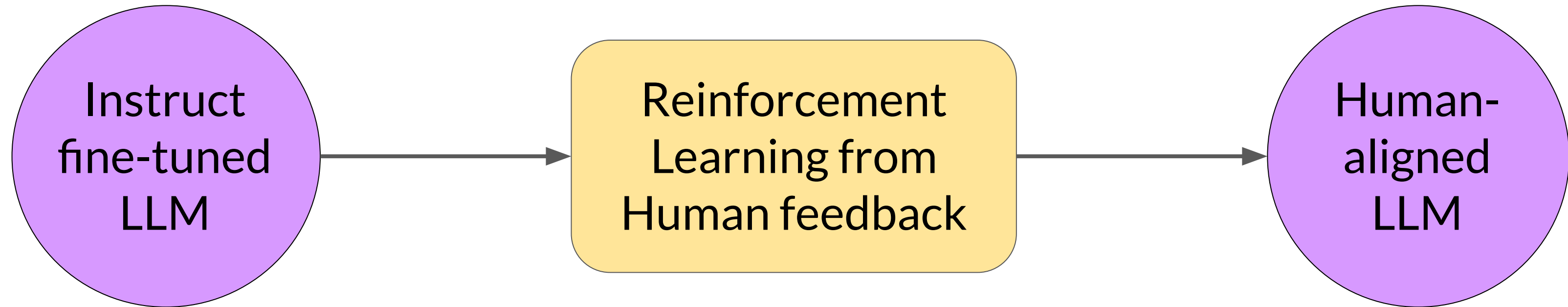
Fine-tuning with human feedback

Fraction of model generated results preferred over human responses



Source:
Stiennon et al. 2020, "Learning to summarize from human feedback"

Reinforcement learning from human feedback (RLHF)



- Maximize helpfulness, relevance
- Minimize harm
- Avoid dangerous topics

Reinforcement learning (RL)

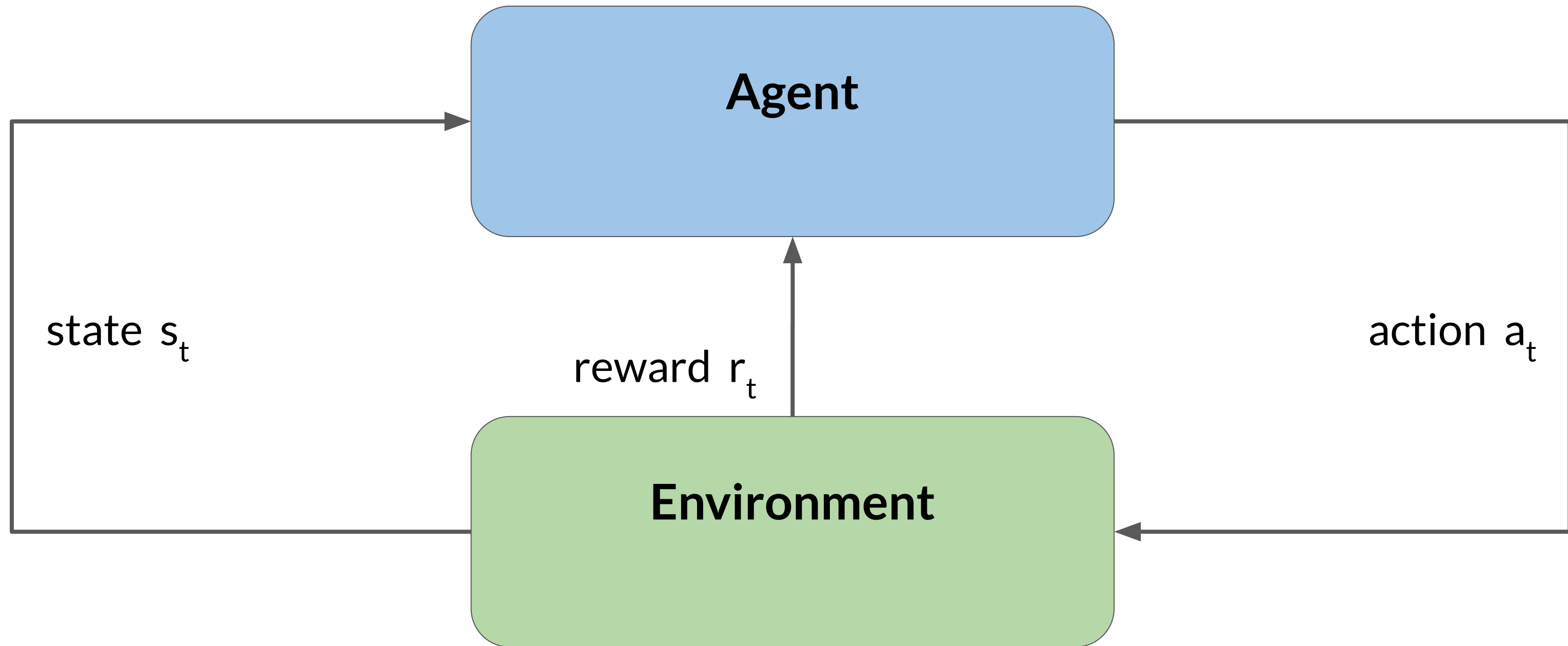


Agent

Objective: maximize reward received for actions

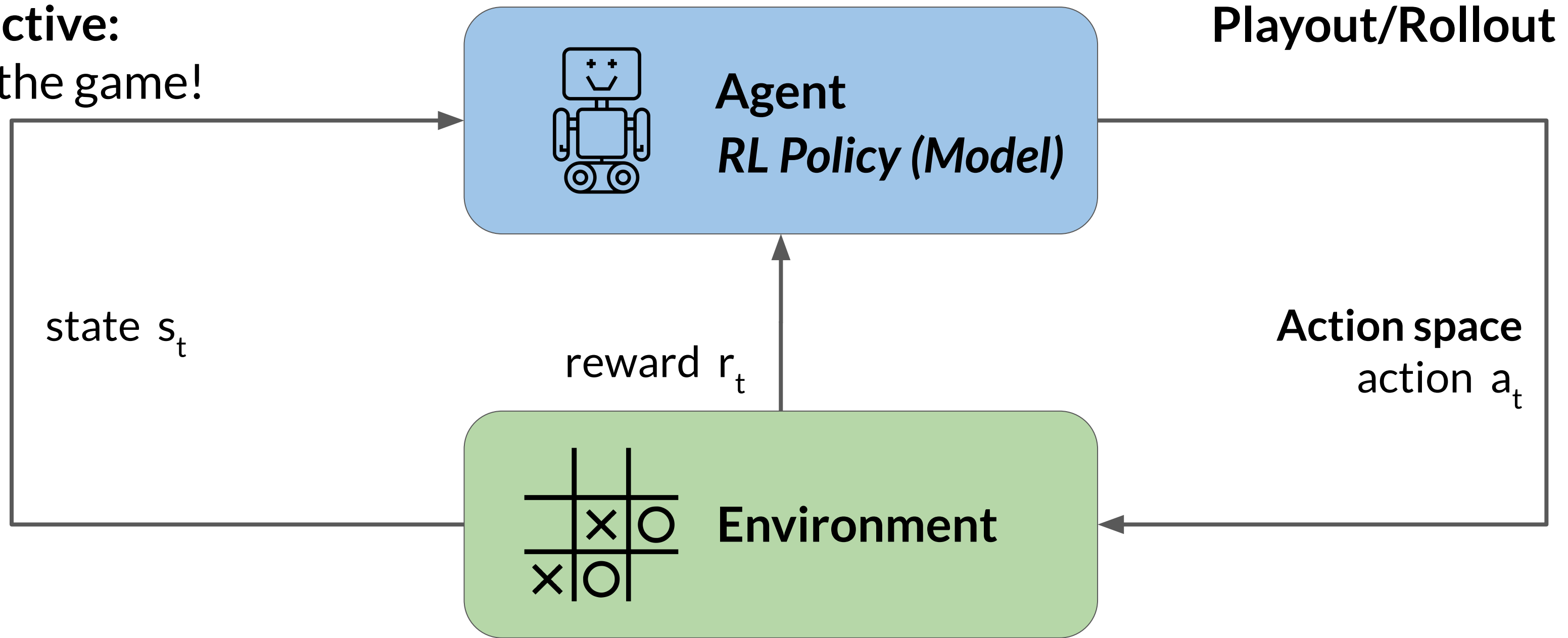
Environment

Reinforcement learning (RL)



Reinforcement learning: Tic-Tac-Toe

Objective:
Win the game!

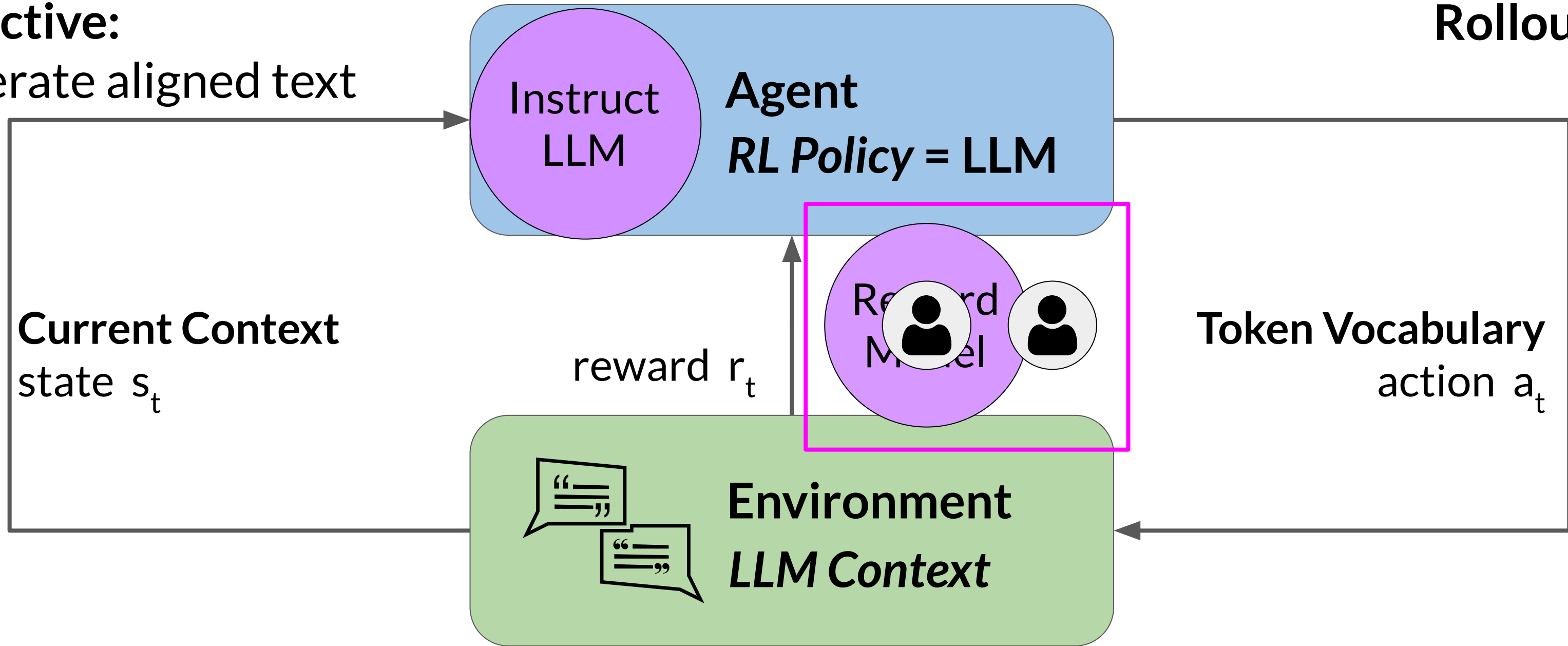


Reinforcement learning: fine-tune LLMs

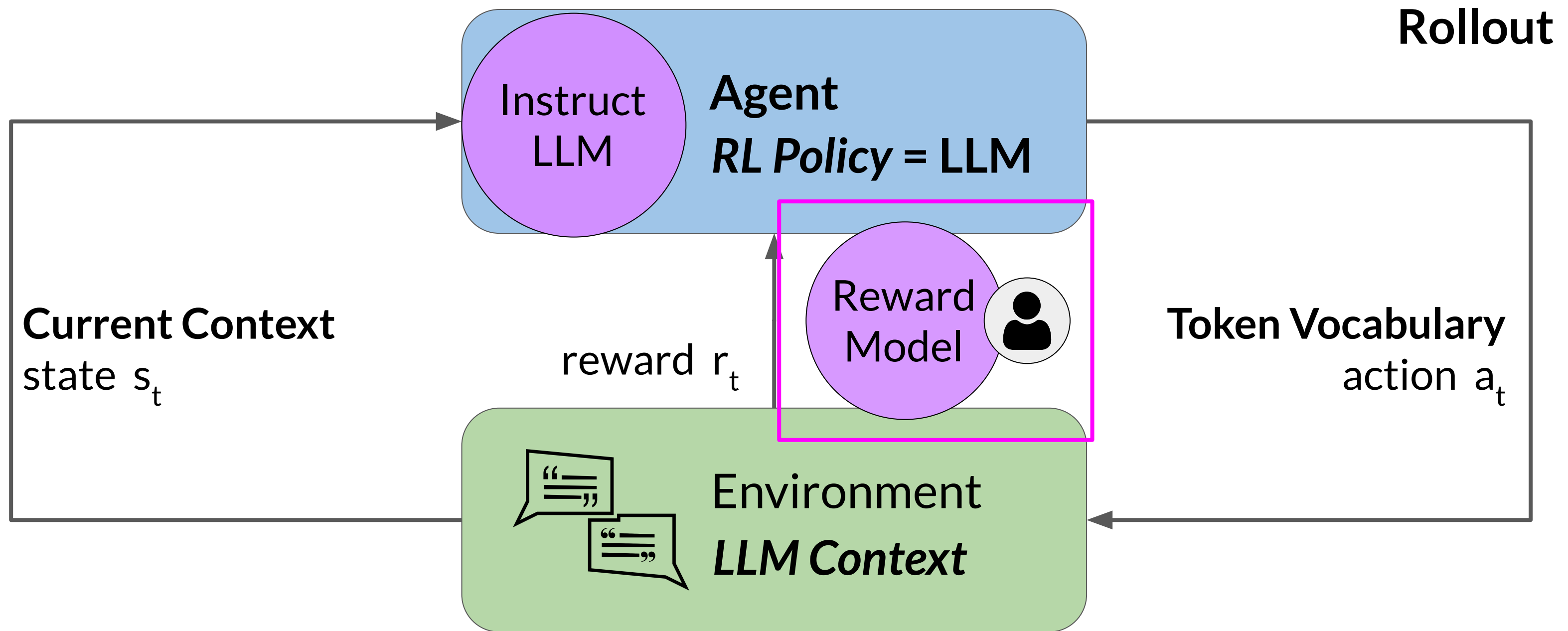
Objective:

Generate aligned text

Rollout

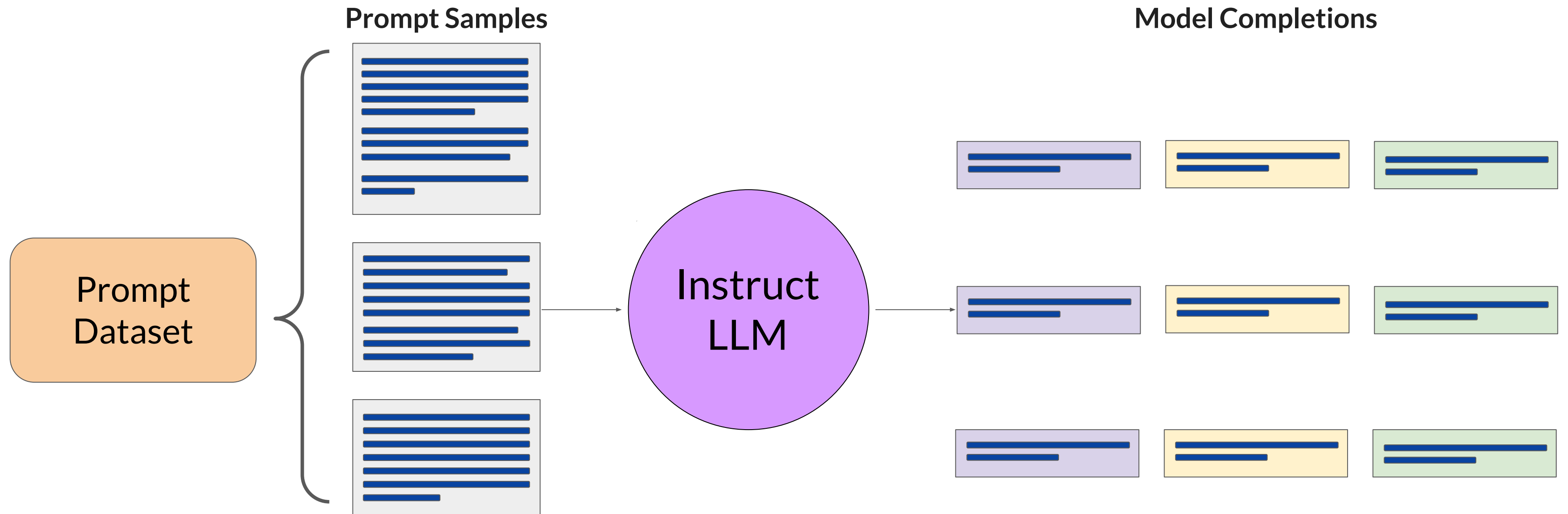


Reinforcement learning: fine-tune LLMs



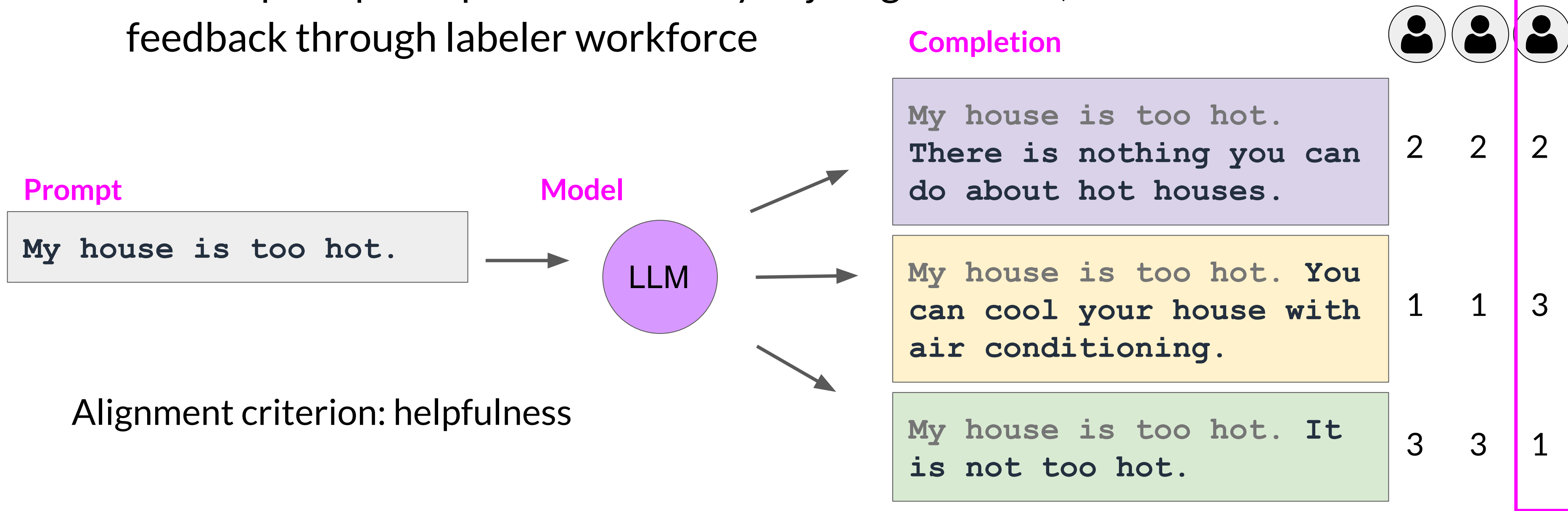
Collecting human feedback

Prepare dataset for human feedback



Collect human feedback

- Define your model alignment criterion
- For the prompt-response sets that you just generated, obtain human feedback through labeler workforce



Sample instructions for human labelers

* Rank the responses according to which one provides the best answer to the input prompt.

* What is the best answer? Make a decision based on (a) the correctness of the answer, and (b) the informativeness of the response. For (a) you are allowed to search the web. Overall, use your best judgment to rank answers based on being the most useful response, which we define as one which is at least somewhat correct, and minimally informative about what the prompt is asking for.

* If two responses provide the same correctness and informativeness by your judgment, and there is no clear winner, you may rank them the same, but please only use this sparingly.

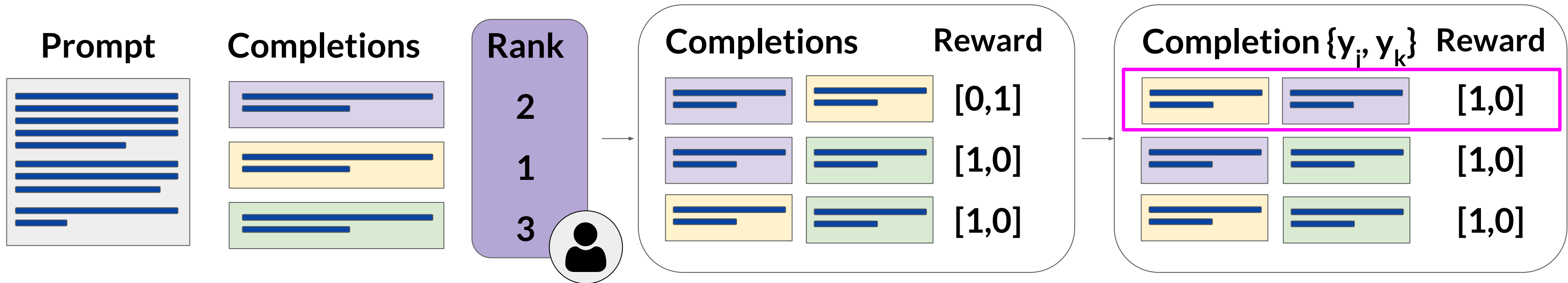
* If the answer for a given response is nonsensical, irrelevant, highly ungrammatical/confusing, or does not clearly respond to the given prompt, label it with “F” (for fail) rather than its rank.

* Long answers are not always the best. Answers which provide succinct, coherent responses may be better than longer ones, if they are at least as correct and informative.

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

Prepare labeled data for training

- Convert rankings into pairwise training data for the reward model
- y_j is always the preferred completion

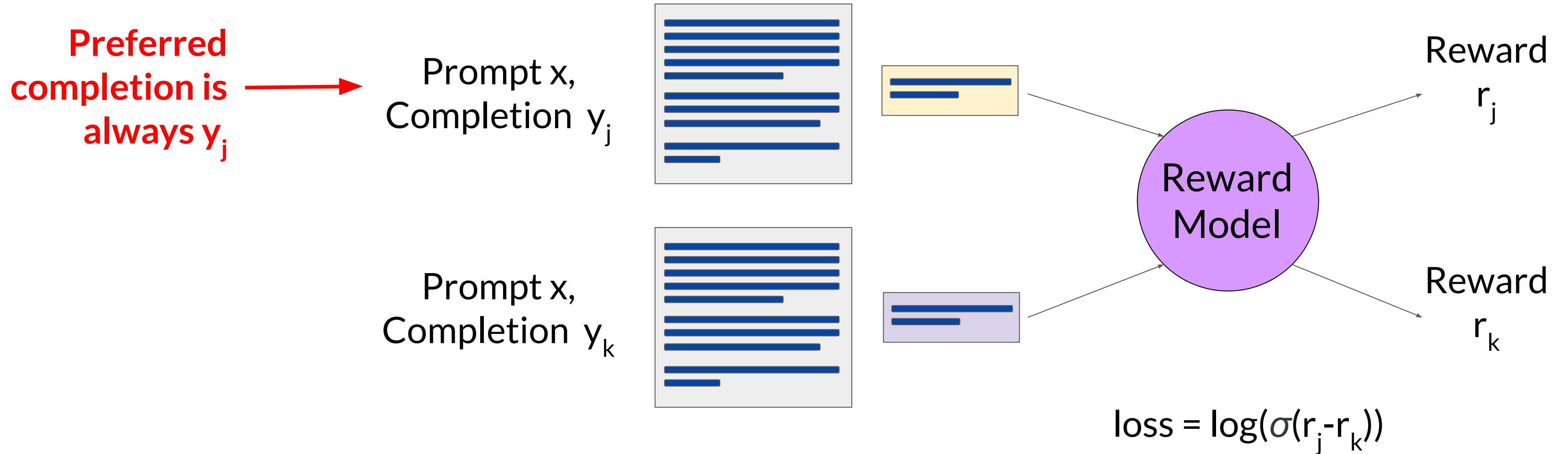


Source: Stiennon et al. 2020, "Learning to summarize from human feedback"

Training the reward model

Train reward model

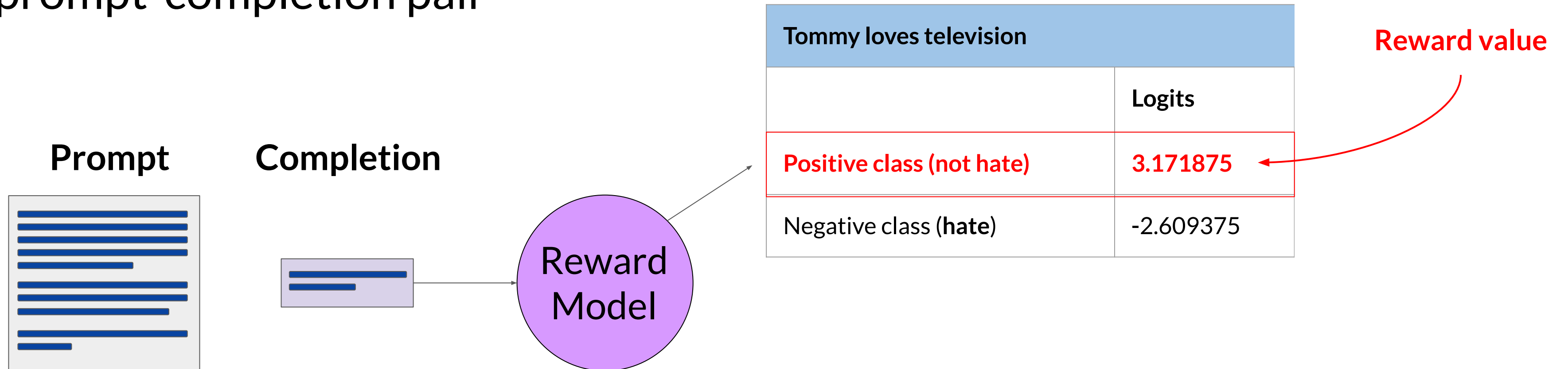
Train model to predict preferred completion from $\{y_j, y_k\}$ for prompt x



Source: Stiennon et al. 2020, "Learning to summarize from human feedback"

Use the reward model

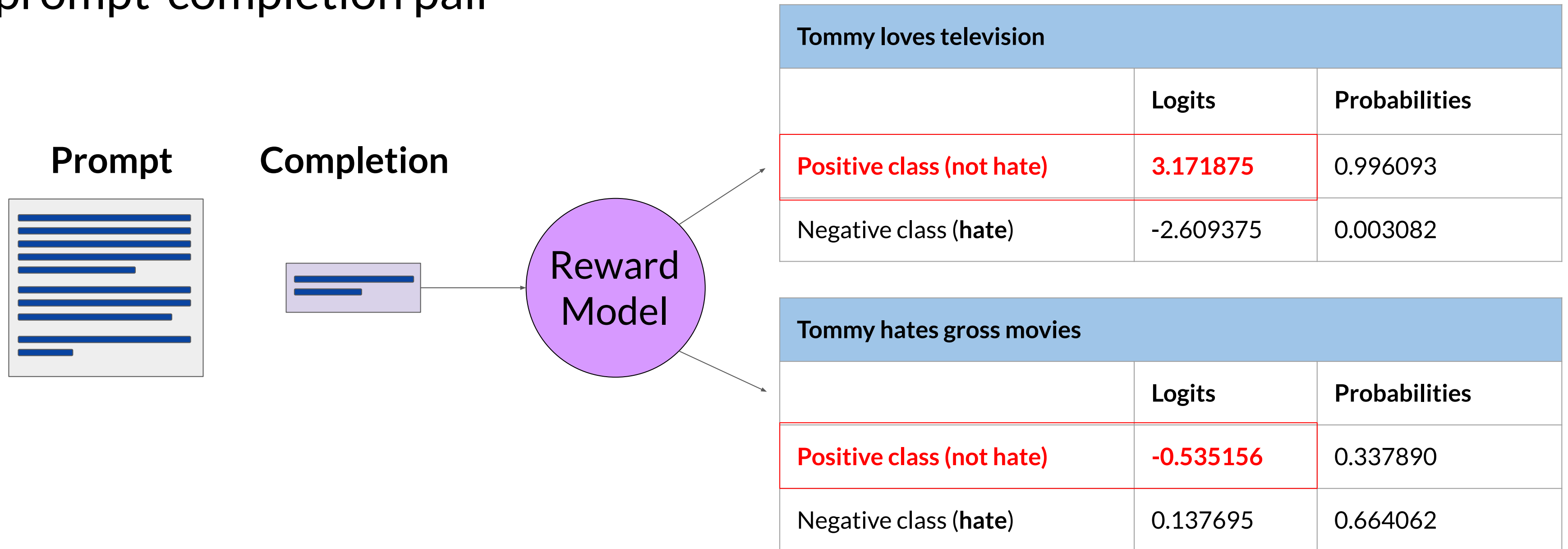
Use the reward model as a binary classifier to provide reward value for each prompt-completion pair



Source: Stiennon et al. 2020, "Learning to summarize from human feedback"

Use the reward model

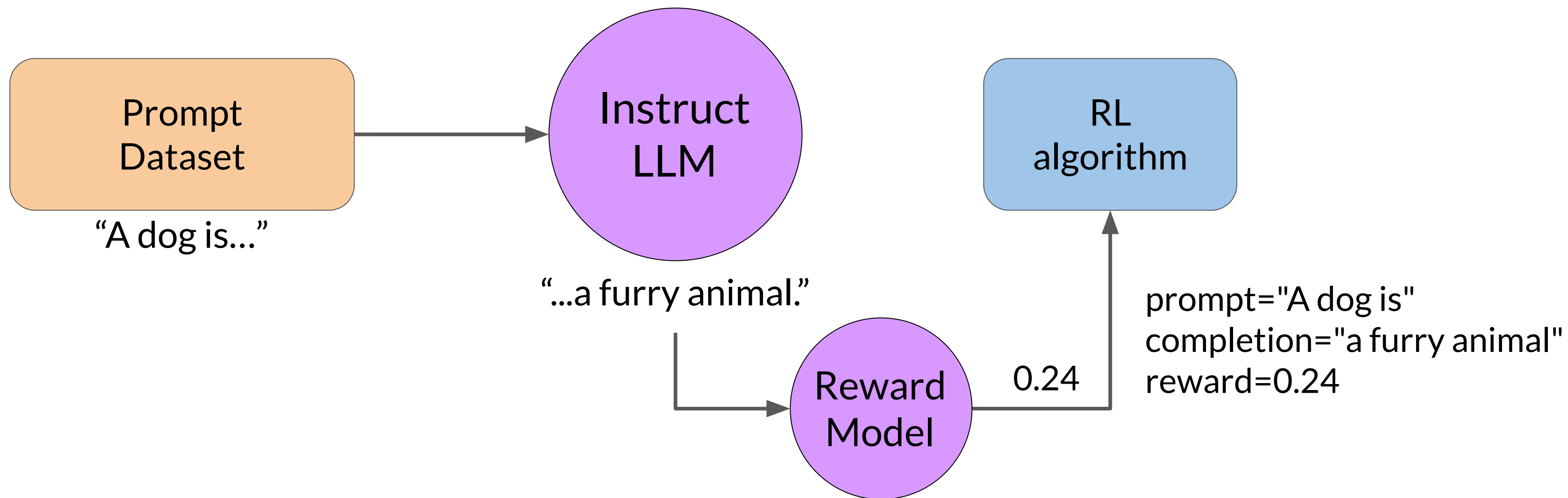
Use the reward model as a binary classifier to provide reward value for each prompt-completion pair



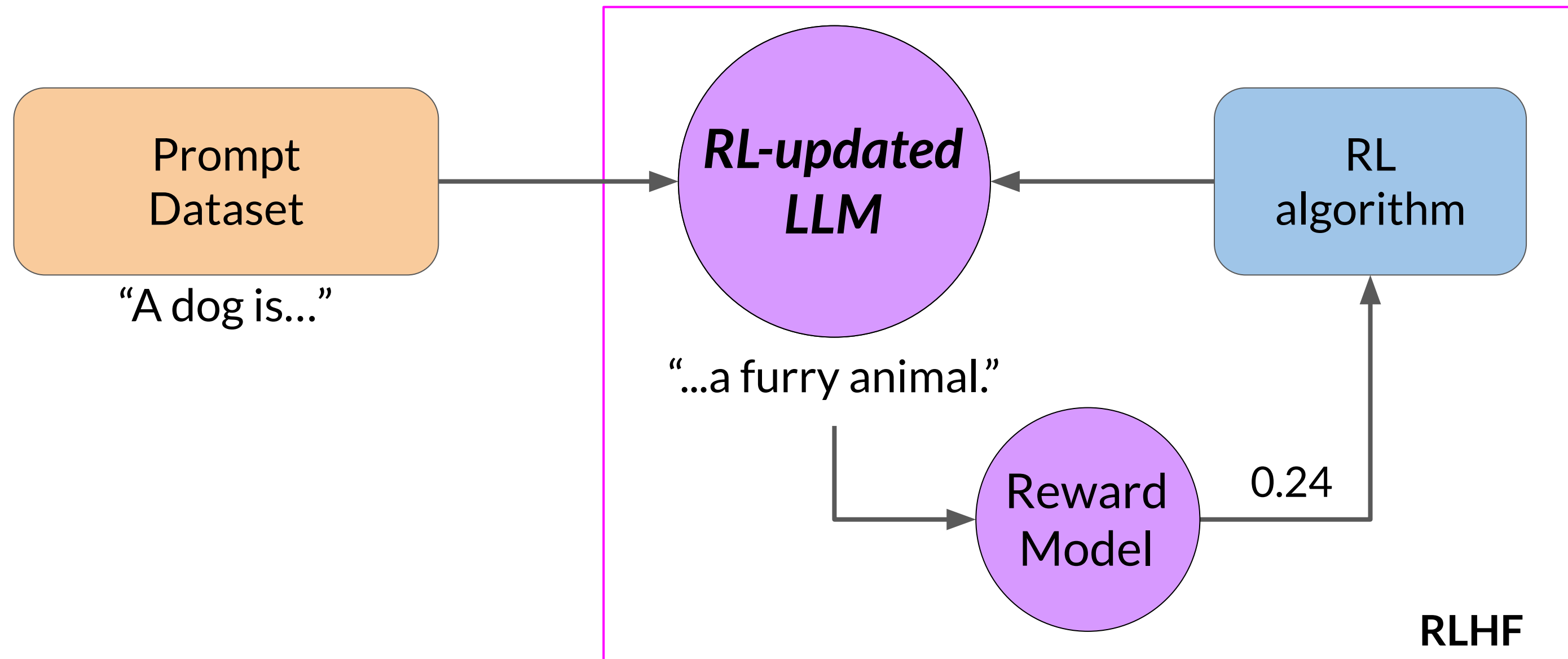
Source: Stiennon et al. 2020, "Learning to summarize from human feedback"

Fine-tuning with RLHF

Use the reward model to fine-tune LLM with RL

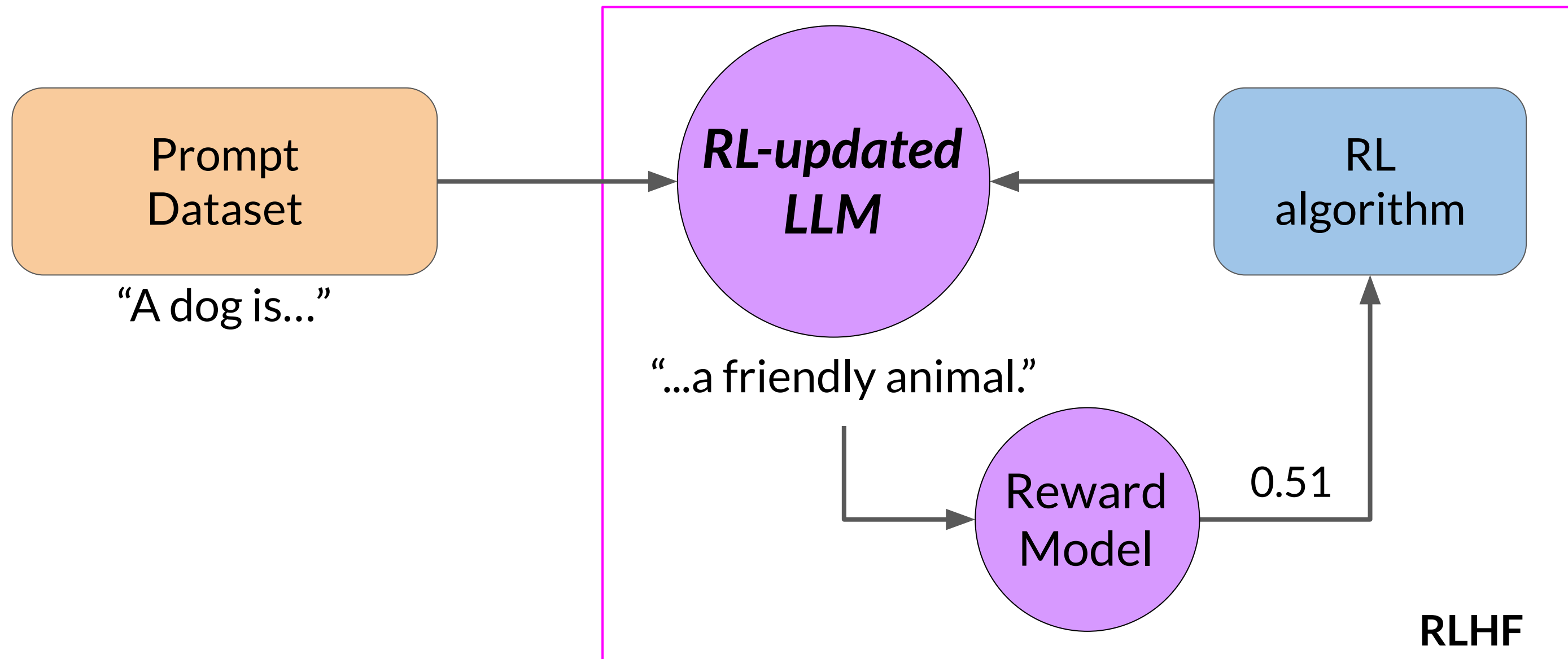


Use the reward model to fine-tune LLM with RL



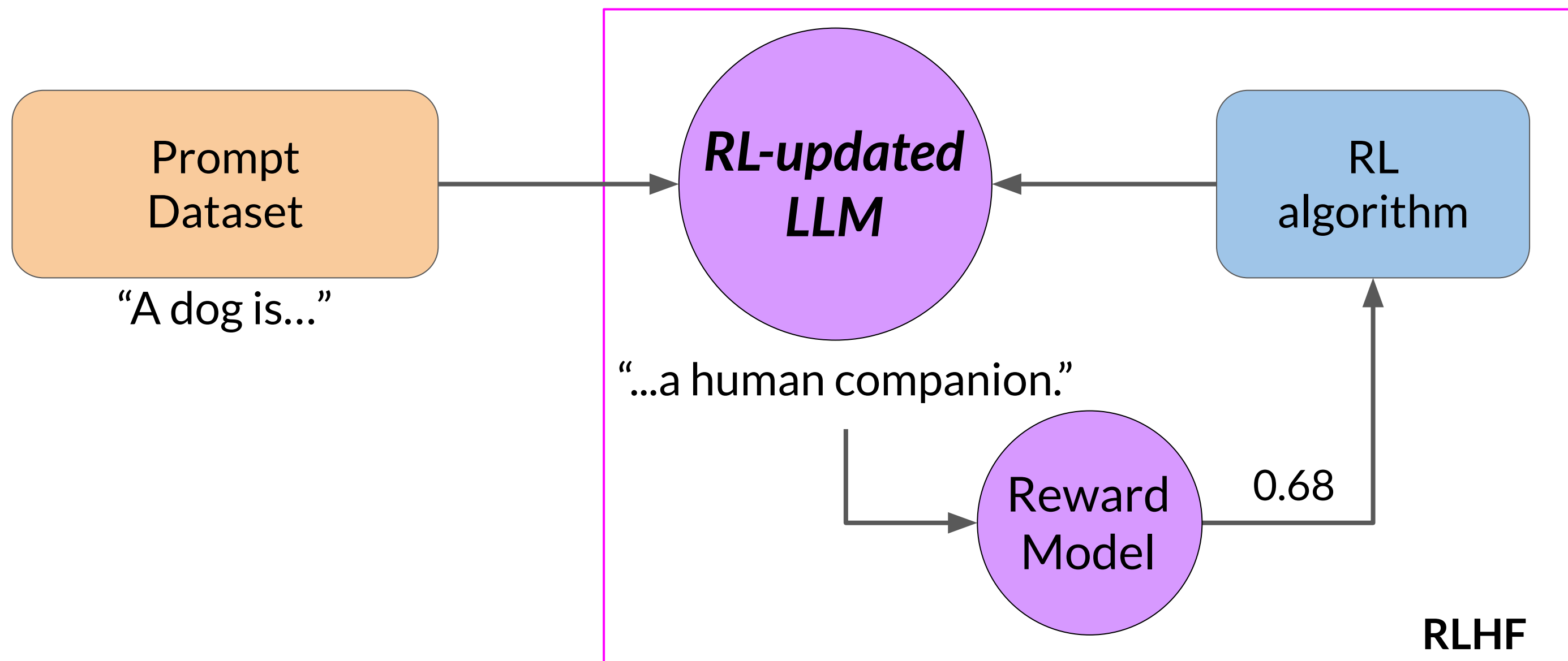
Iteration 1

Use the reward model to fine-tune LLM with RL



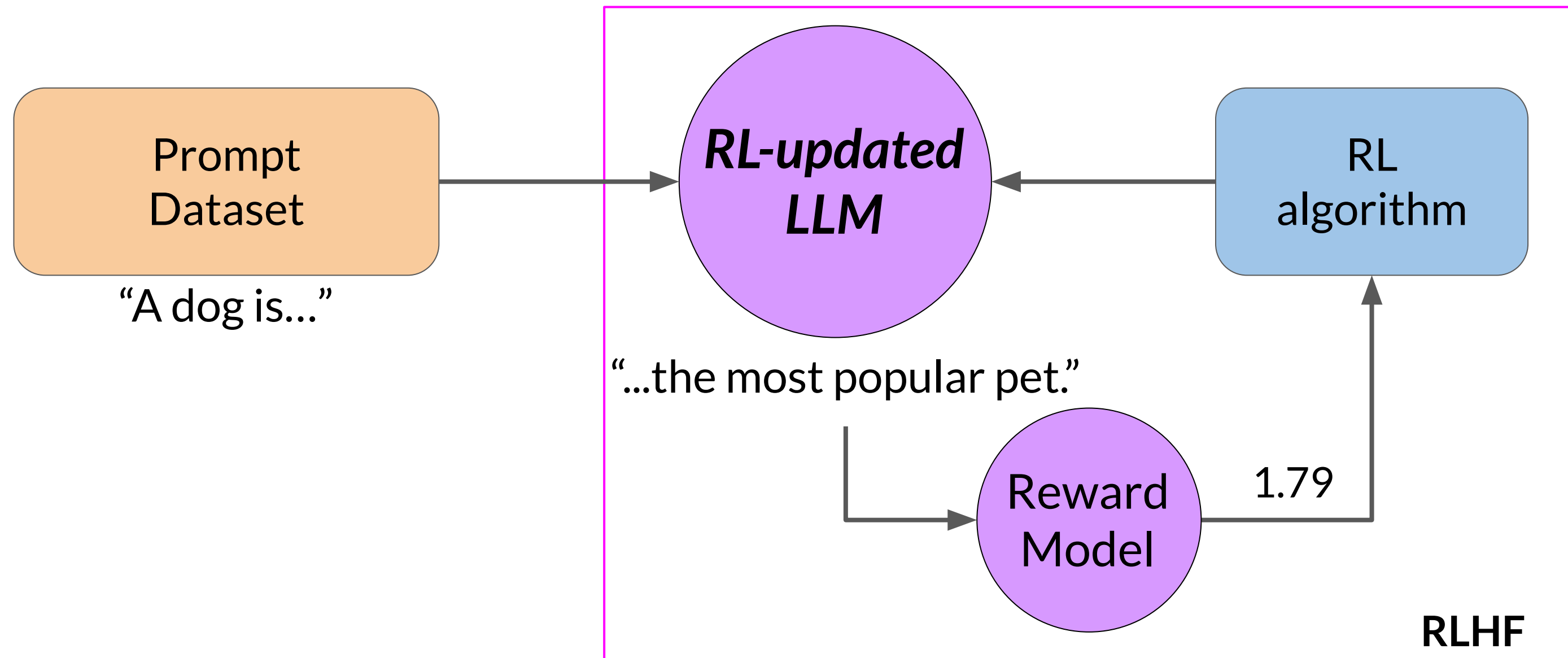
Iteration 2

Use the reward model to fine-tune LLM with RL

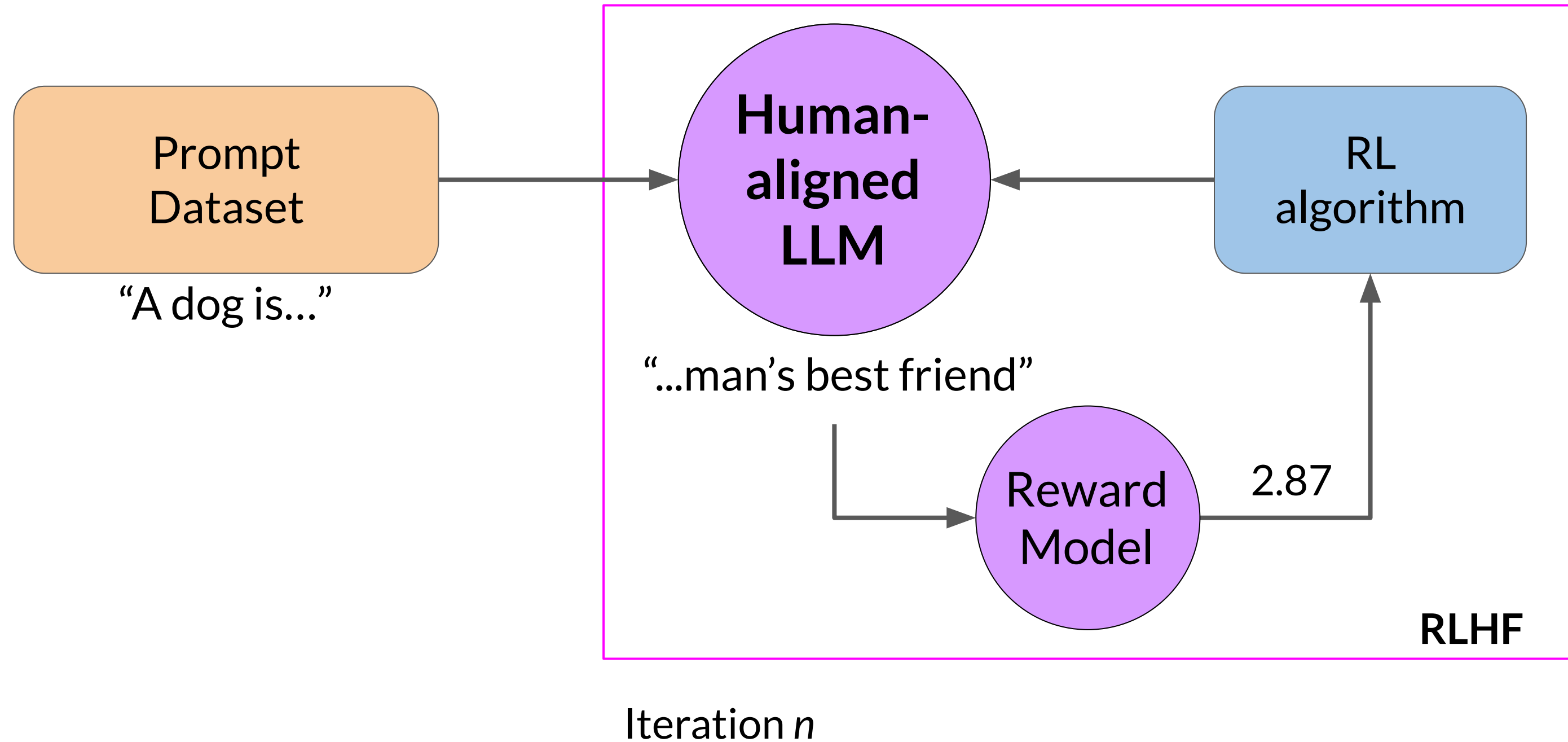


Iteration 3

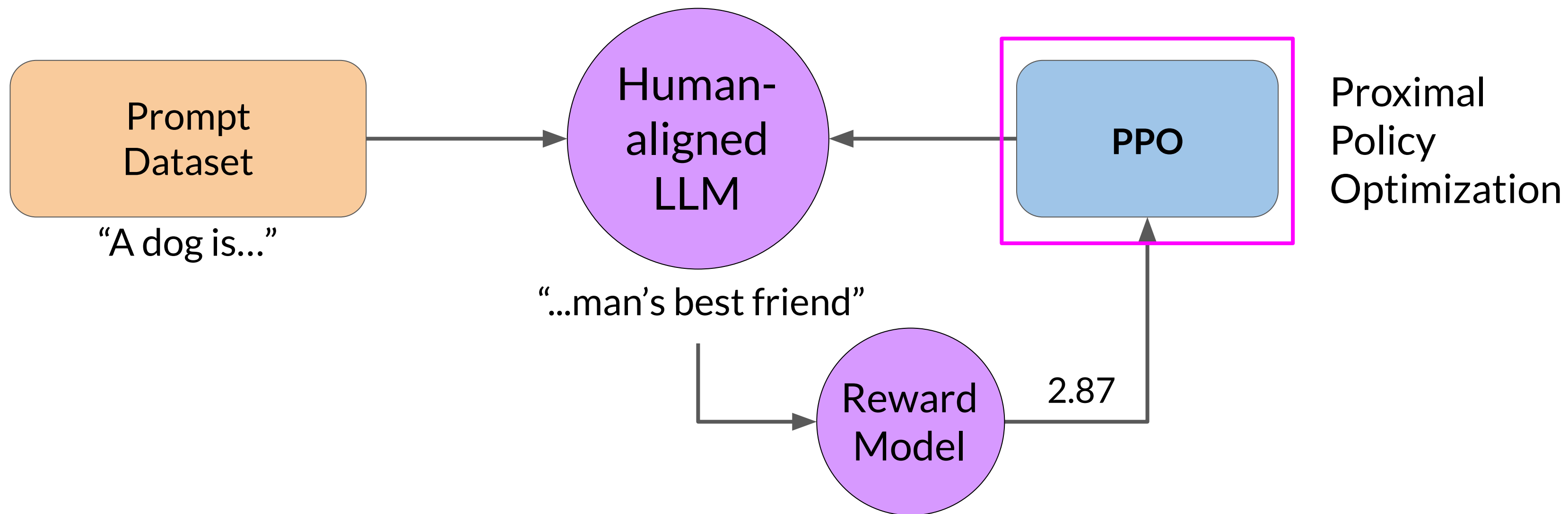
Use the reward model to fine-tune LLM with RL



Use the reward model to fine-tune LLM with RL



Use the reward model to fine-tune LLM with RL

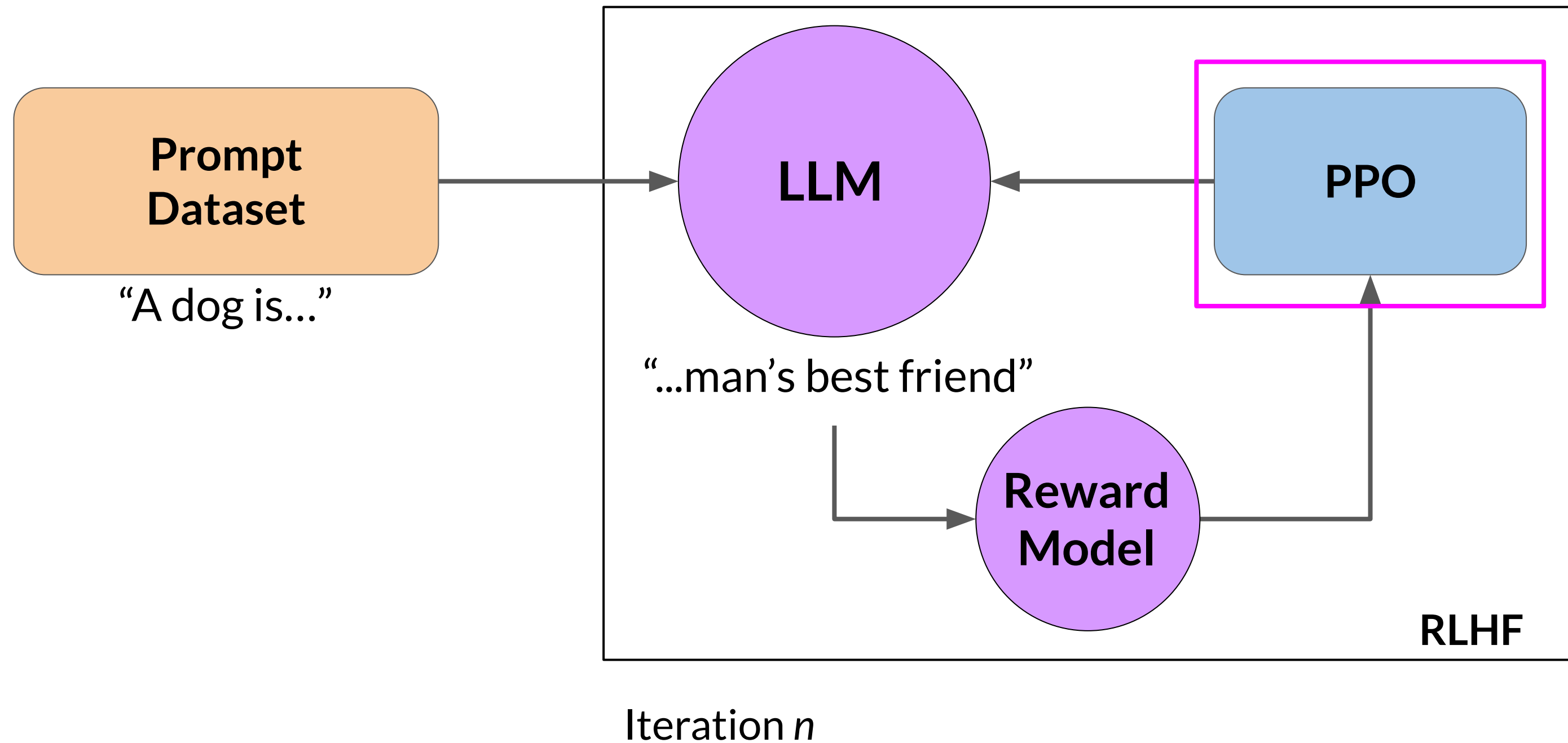




Proximal Policy Optimization

Dr. Ehsan Kamalinejad

Proximal policy optimization (PPO)

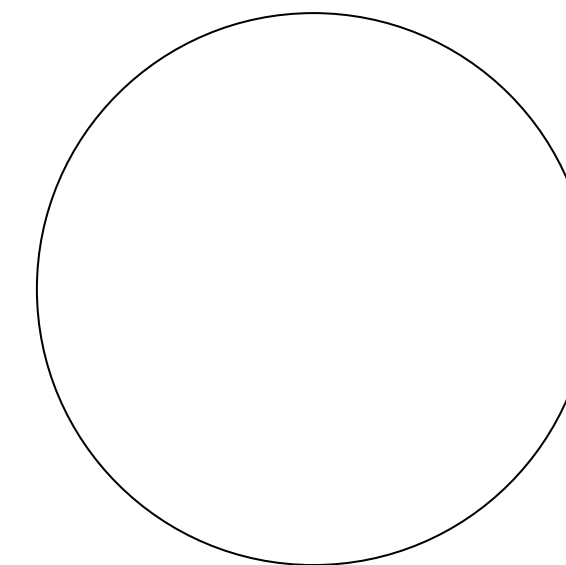


Initialize PPO with Instruct LLM



**Instruct
LLM**

**Phase 1
Create completions**



**Phase 2
Model update**

PPO Phase 1: Create completions

Instruct
LLM

Phase 1
Create completions

Prompt

A dog is

Completion

A dog is
a furry animal

Prompt

This house is

Completion

This house is
very ugly

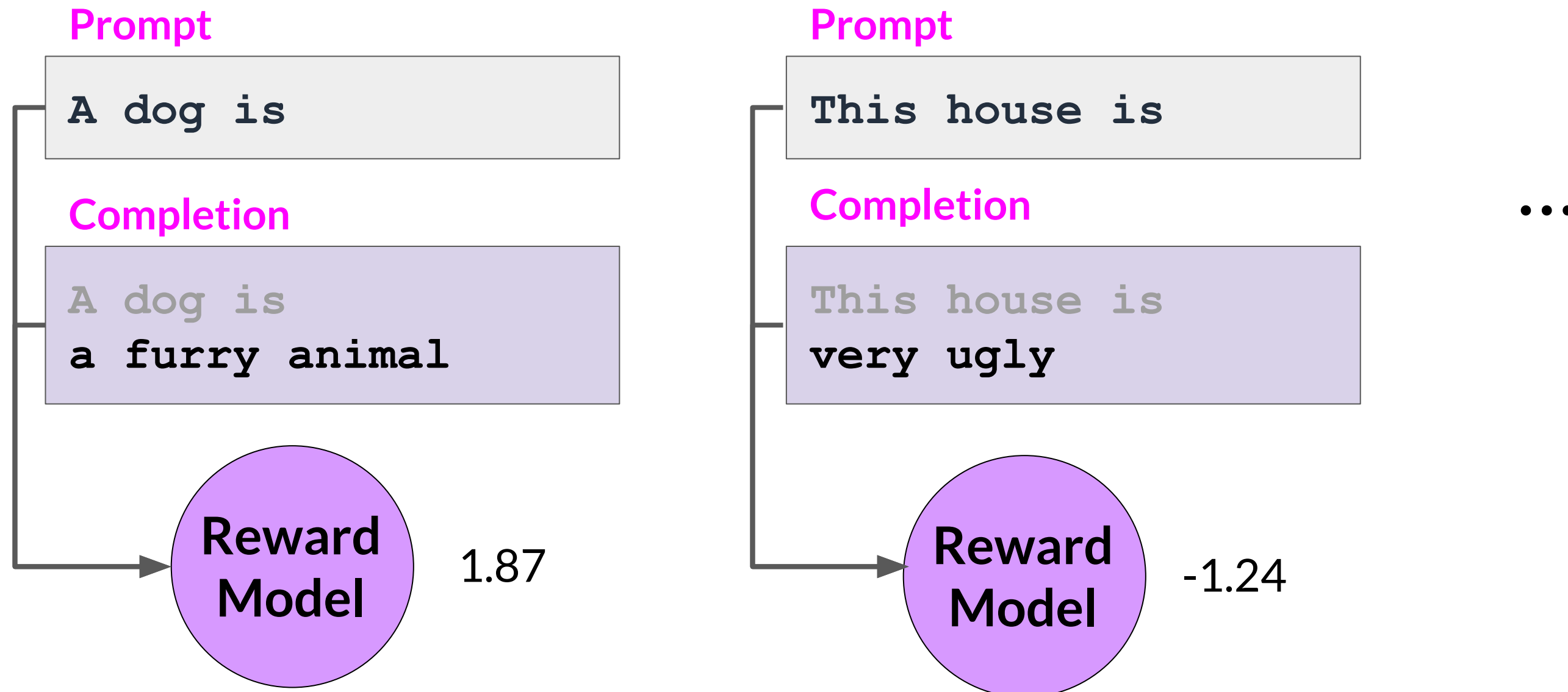
...

Experiments

to assess the
outcome of the
current model,

e.g. how
helpful,
harmless,
honest the
model is

Calculate rewards



Calculate value loss

Prompt

A dog is

Completion

A dog is
a ...

Value
function

$$L^{VF} = \frac{1}{2} \left\| \underbrace{V_{\theta}(s)}_{\substack{\text{Estimated} \\ \text{future total reward}}} - \left(\sum_{t=0}^T \gamma^t r_t \mid s_0 = s \right) \right\|_2^2$$

0.34

Calculate value loss

Prompt

A dog is

Completion

A dog is
a furry...

Value
function

$$L^{VF} = \frac{1}{2} \left\| \underbrace{V_{\theta}(s)}_{\text{Estimated future total reward}} - \left(\sum_{t=0}^T \gamma^t r_t \mid s_0 = s \right) \right\|_2^2$$

1.23

Calculate value loss

Prompt

A dog is

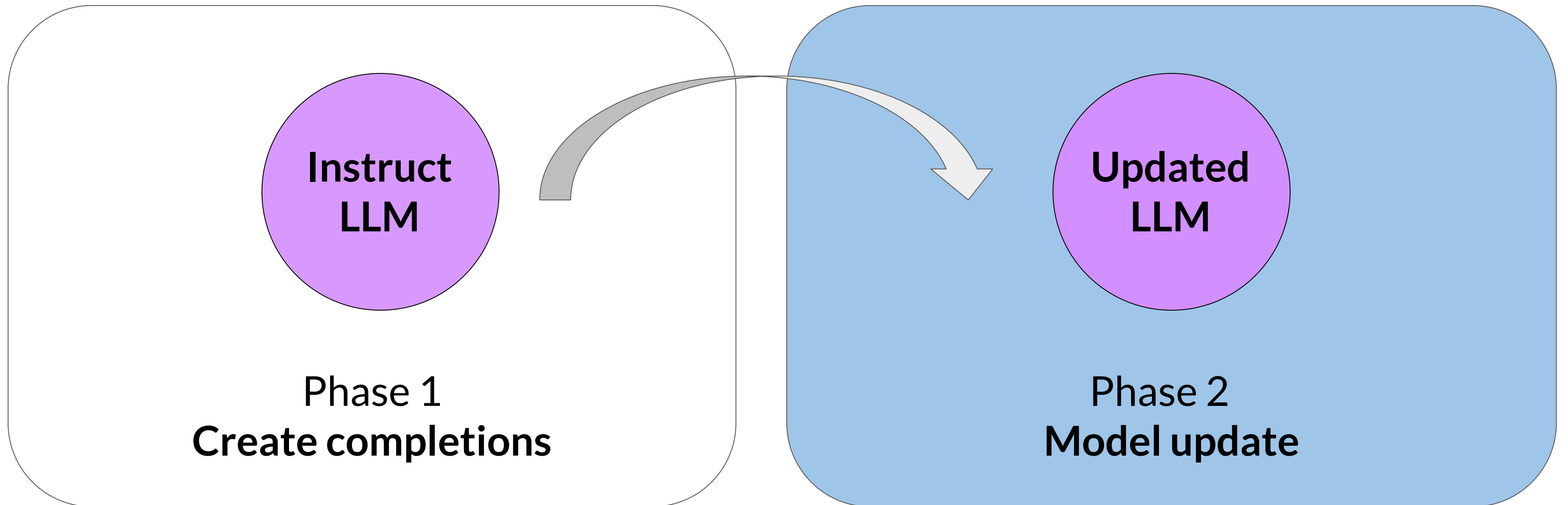
Completion

A dog is
a furry...

Value
loss

$$L^{VF} = \frac{1}{2} \left\| \underbrace{V_{\theta}(s)}_{\substack{\text{Estimated} \\ \text{future total reward} \\ 1.23}} - \underbrace{\left(\sum_{t=0}^T \gamma^t r_t \mid s_0 = s \right)}_{\substack{\text{Known} \\ \text{future total reward} \\ 1.87}} \right\|_2^2$$

PPO Phase 2: Model update



PPO Phase 2: Calculate policy loss

$$L^{POLICY} = \min \left(\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)} \cdot \hat{A}_t, \text{clip} \left(\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)}, 1 - \epsilon, 1 + \epsilon \right) \cdot \hat{A}_t \right)$$

PPO Phase 2: Calculate policy loss

$$L^{POLICY} = \min \left(\underbrace{\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)} \cdot \hat{A}_t}_{\text{Most important expression}}, \text{clip} \left(\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)}, 1 - \epsilon, 1 + \epsilon \right) \cdot \hat{A}_t \right)$$

Most important expression

π_{θ} **Model's probability distribution over tokens**

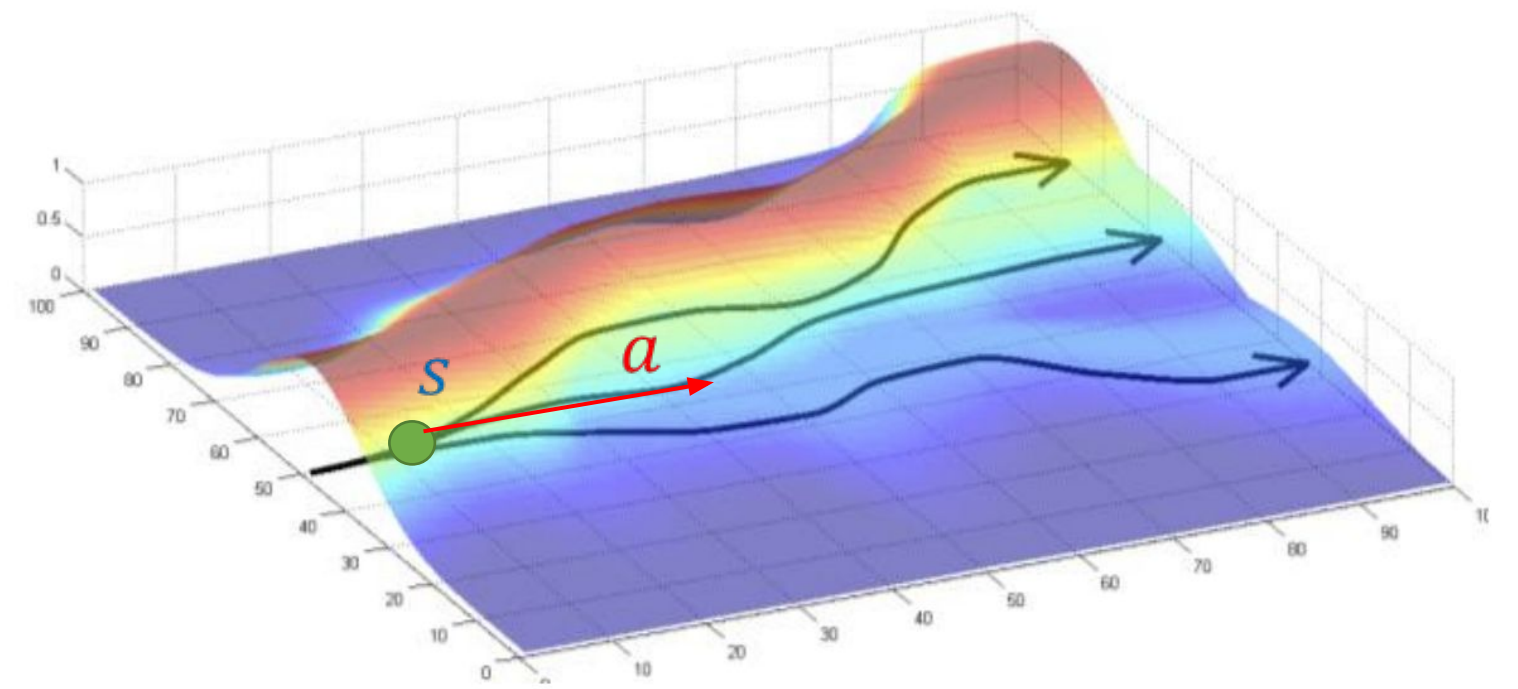
PPO Phase 2: Calculate policy loss

Probabilities of the next token
with the updated LLM


$$L^{POLICY} = \min \left(\frac{\pi_{\theta} (a_t | s_t)}{\pi_{\theta_{old}} (a_t | s_t)} \cdot \hat{A}_t, \text{clip} \left(\frac{\pi_{\theta} (a_t | s_t)}{\pi_{\theta_{old}} (a_t | s_t)}, 1 - \epsilon, 1 + \epsilon \right) \cdot \hat{A}_t \right)$$

Probabilities of the next token
with the initial LLM

Advantage term



PPO Phase 2: Calculate policy loss

$$L^{POLICY} = \min \left(\underbrace{\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)} \cdot \hat{A}_t}_{\text{ratio}}, \underbrace{\text{clip} \left(\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)}, 1 - \epsilon, 1 + \epsilon \right) \cdot \hat{A}_t}_{\text{clipped ratio}} \right)$$


PPO Phase 2: Calculate policy loss

$$L^{POLICY} = \min \left(\underbrace{\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)} \cdot \hat{A}_t}_{\text{Defines "trust region"}}, \underbrace{\text{clip} \left(\frac{\pi_{\theta}(a_t | s_t)}{\pi_{\theta_{old}}(a_t | s_t)}, 1 - \epsilon, 1 + \epsilon \right) \cdot \hat{A}_t}_{\text{Guardrails: Keeping the policy in the "trust region"}} \right)$$

Guardrails:
Keeping the policy in the "trust region"

PPO Phase 2: Calculate entropy loss

$$L^{ENT} = \text{entropy}(\pi_{\theta}(\cdot | s_t))$$

Low entropy:

Prompt

A dog is

Completion

A dog is
a domesticated
carnivorous mammal

Prompt

A dog is

Completion

A dog is
a small carnivorous
mammal

High entropy:

Prompt

A dog is

Completion

A dog is
is one of the most
popular pets around
the world

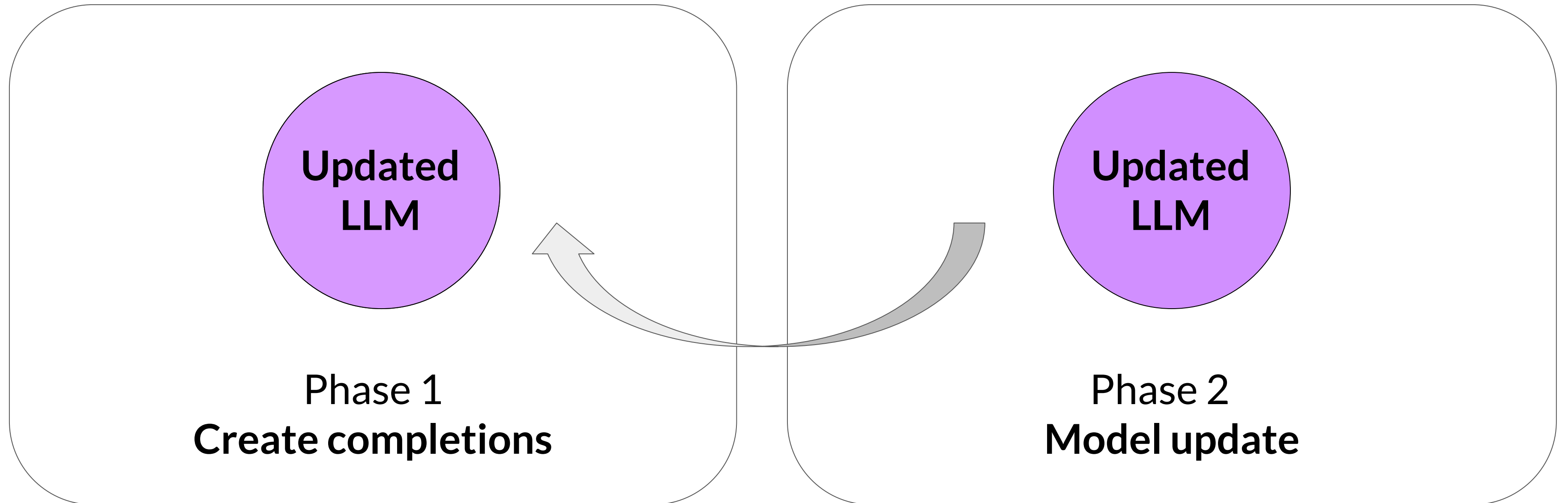
PPO Phase 2: Objective function

$$L^{PPO} = \underbrace{L^{POLICY}}_{\text{Policy loss}} + \underbrace{c_1 L^{VF}}_{\text{Value loss}} + \underbrace{c_2 L^{ENT}}_{\text{Entropy loss}}$$

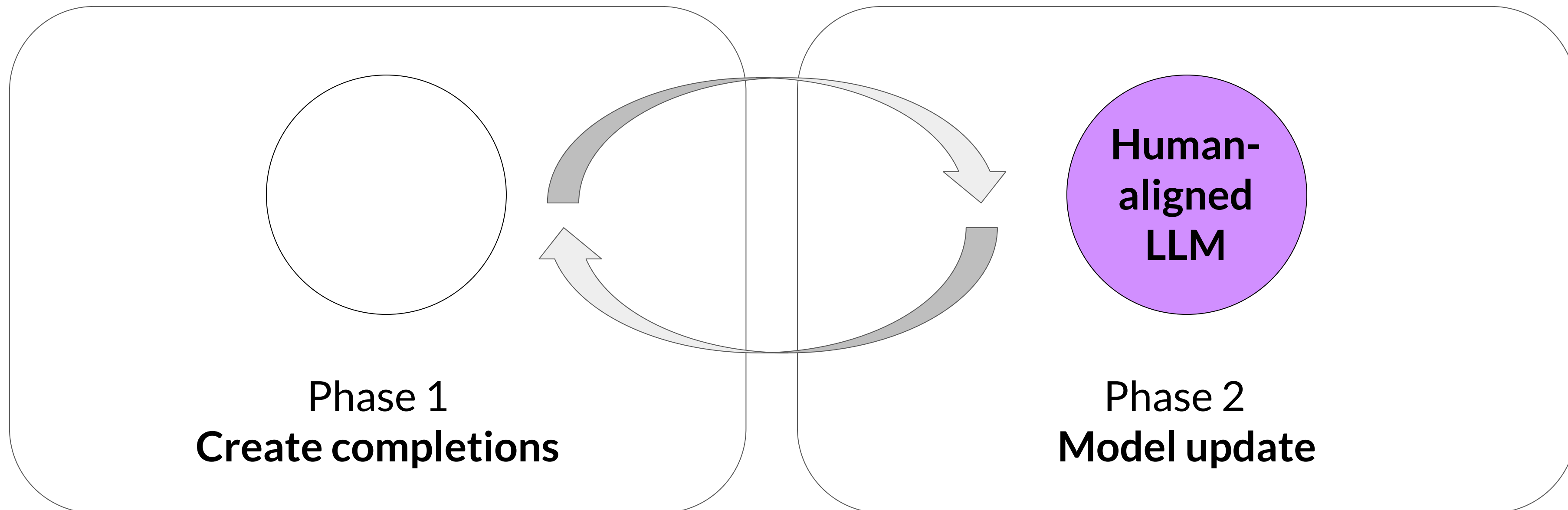
Hyperparameters

The diagram illustrates the PPO objective function. The equation is $L^{PPO} = L^{POLICY} + c_1 L^{VF} + c_2 L^{ENT}$. Below the equation, three purple brackets group the terms: L^{POLICY} is labeled 'Policy loss', $c_1 L^{VF}$ is labeled 'Value loss', and $c_2 L^{ENT}$ is labeled 'Entropy loss'. Above the equation, the word 'Hyperparameters' has two arrows pointing to the coefficients c_1 and c_2 .

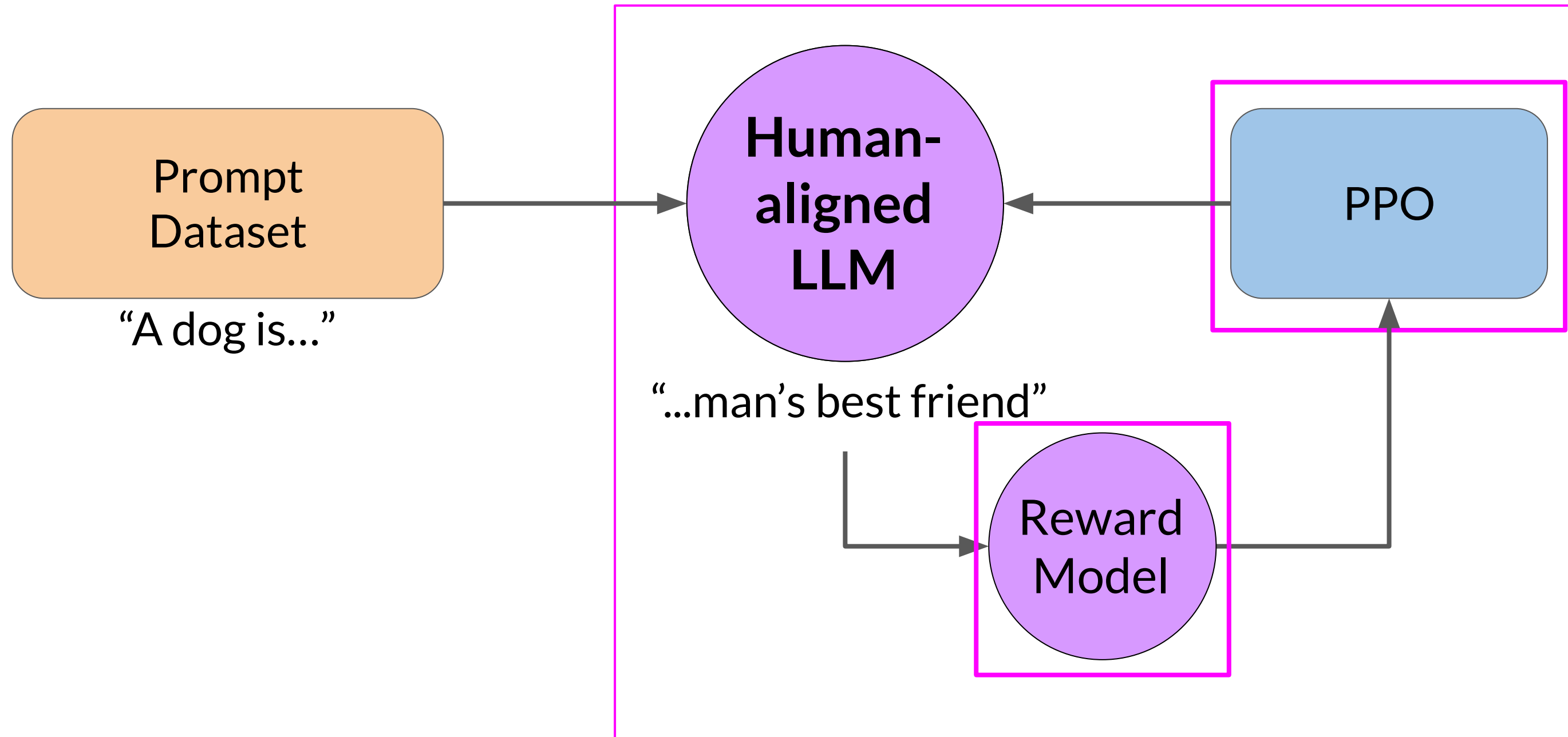
Replace LLM with updated LLM



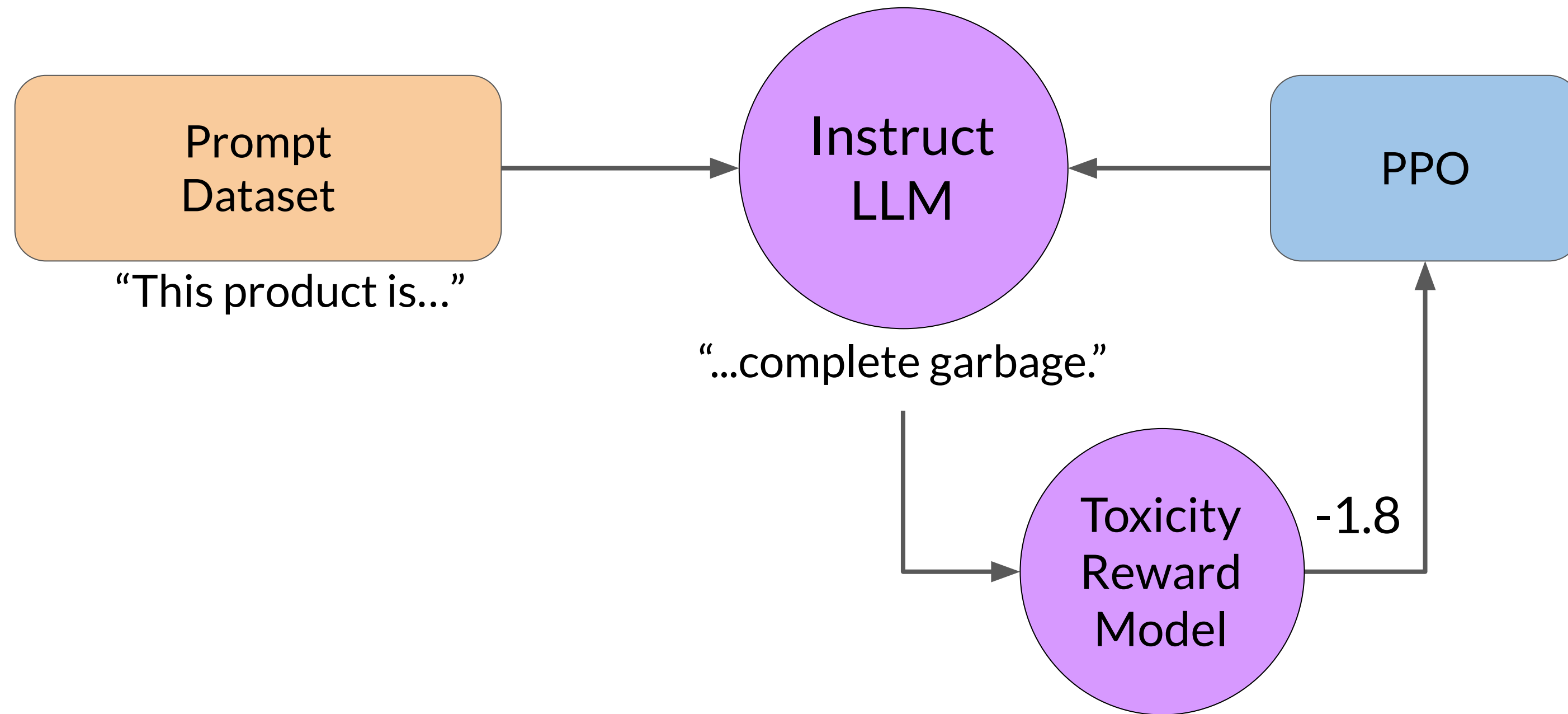
After many iterations, human-aligned LLM!



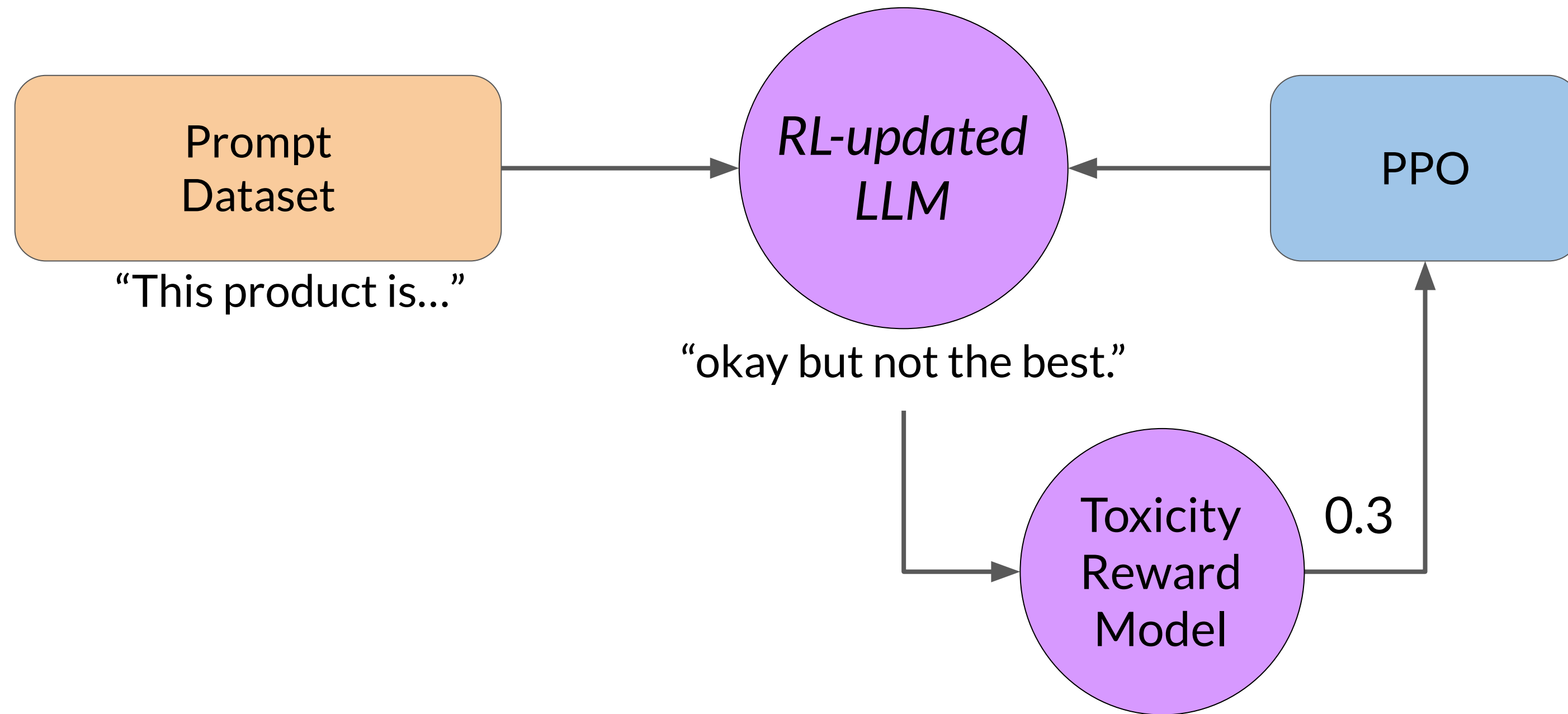
Fine-tuning LLMs with RLHF



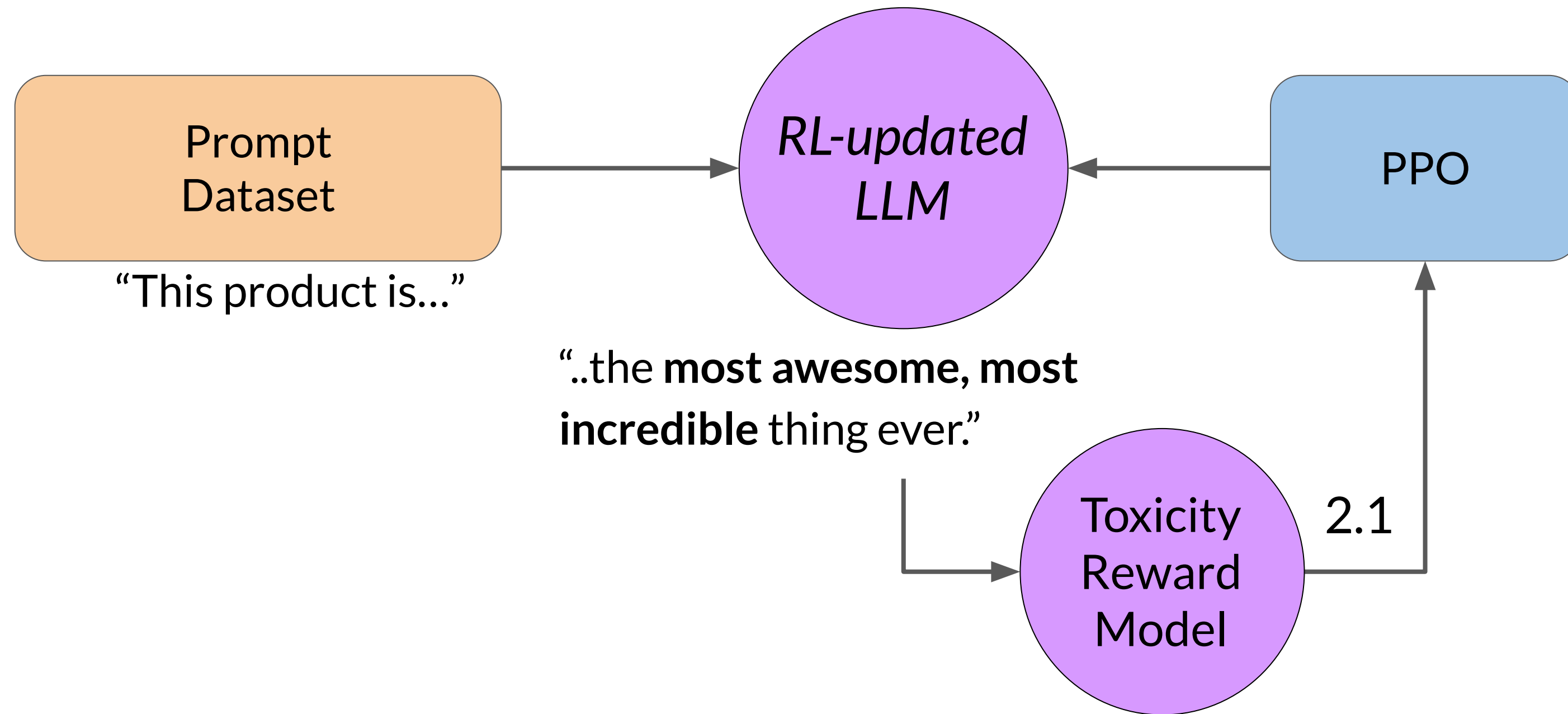
Potential problem: reward hacking



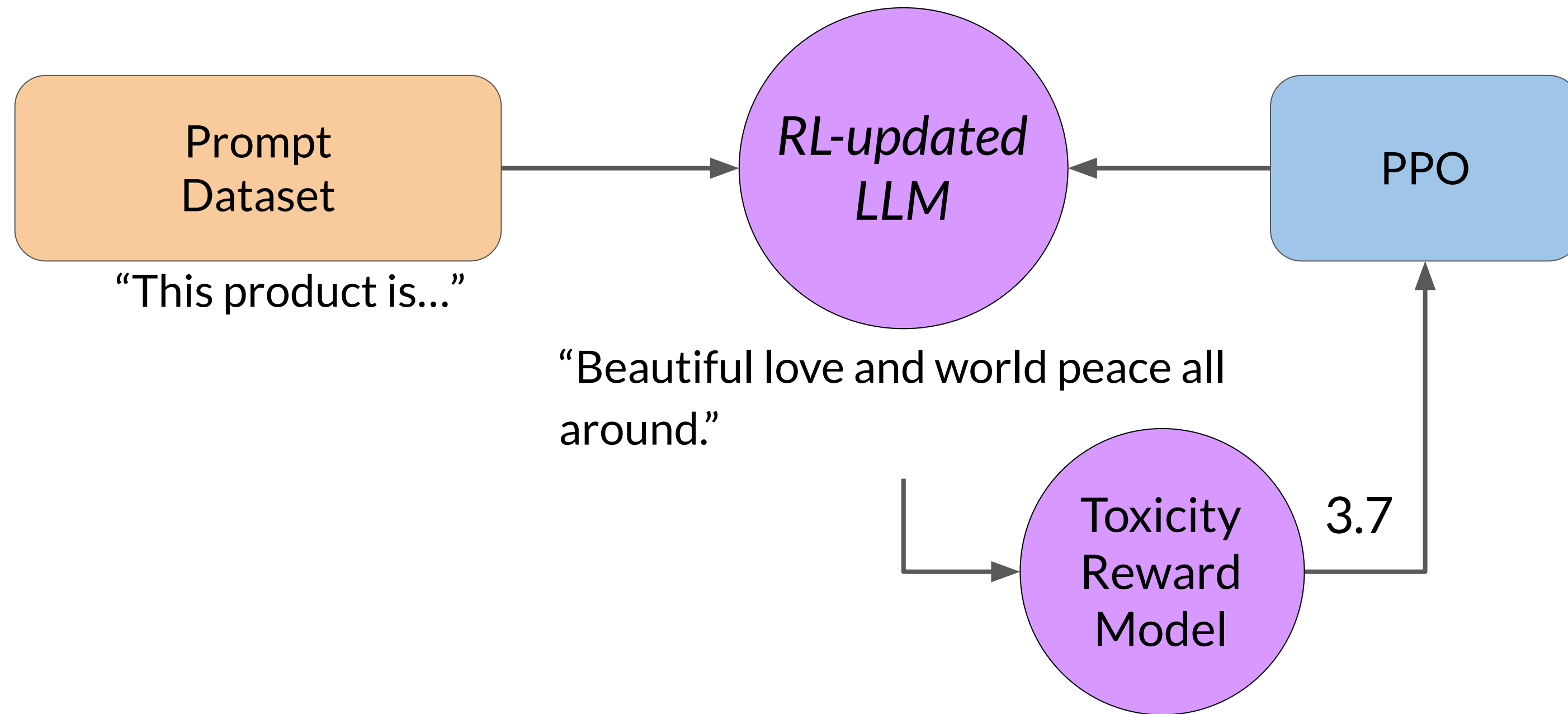
Potential problem: reward hacking



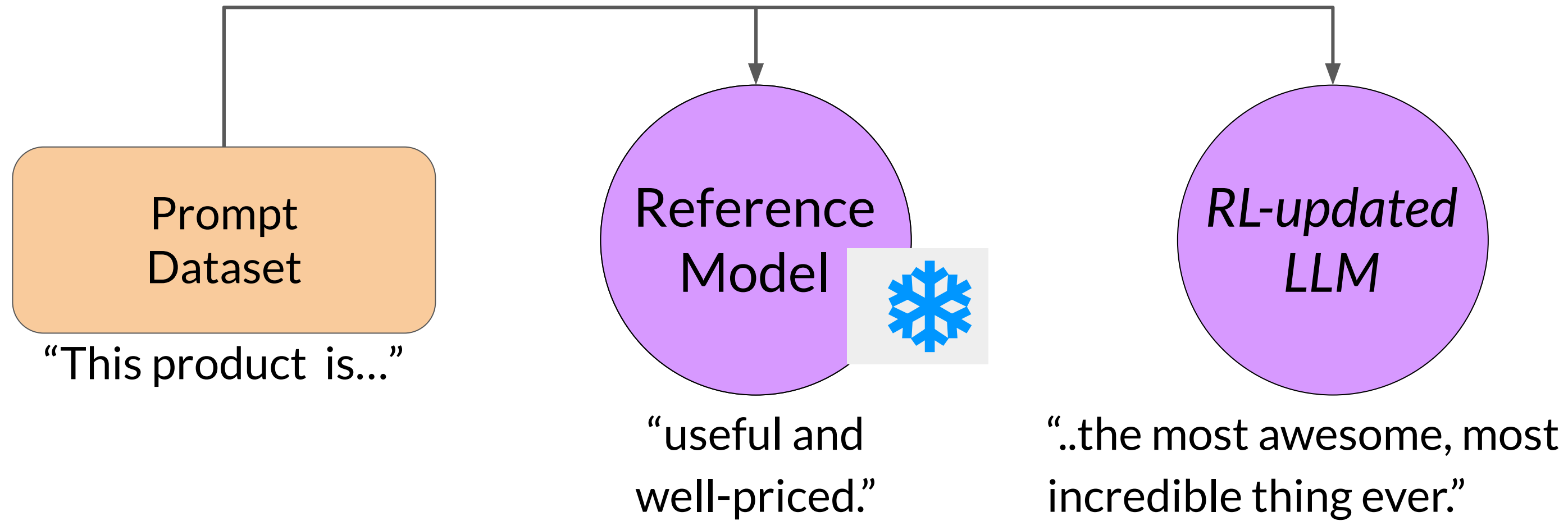
Potential problem: reward hacking



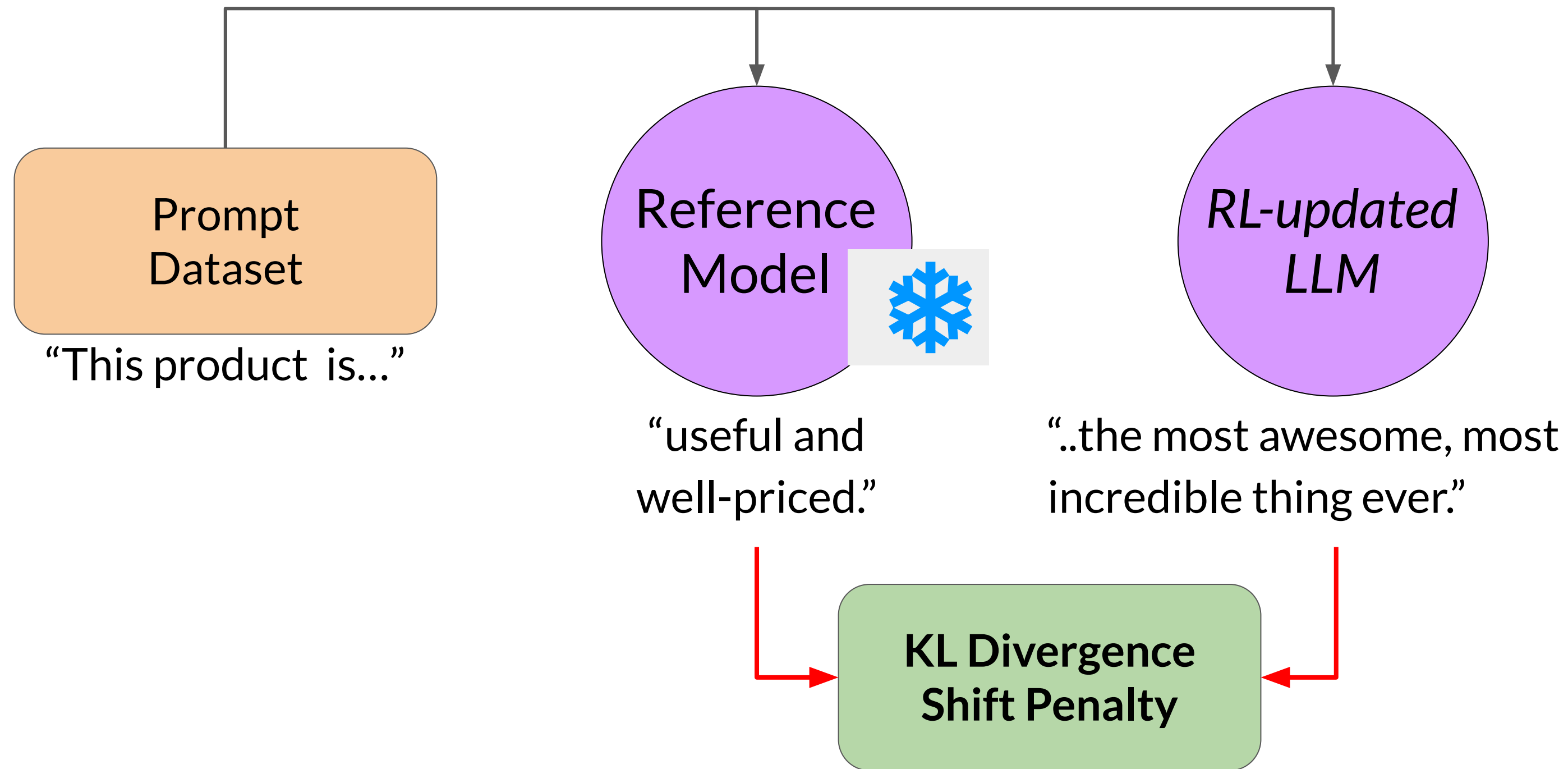
Potential problem: reward hacking



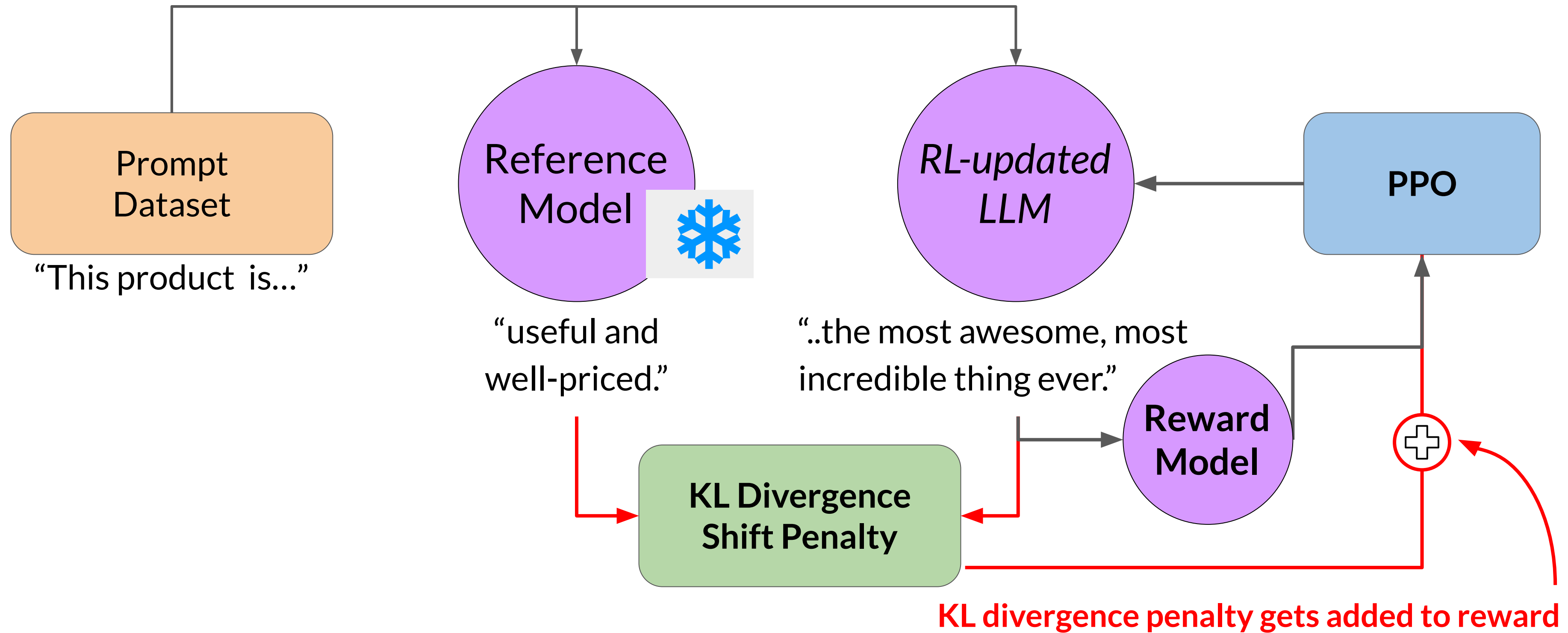
Avoiding reward hacking



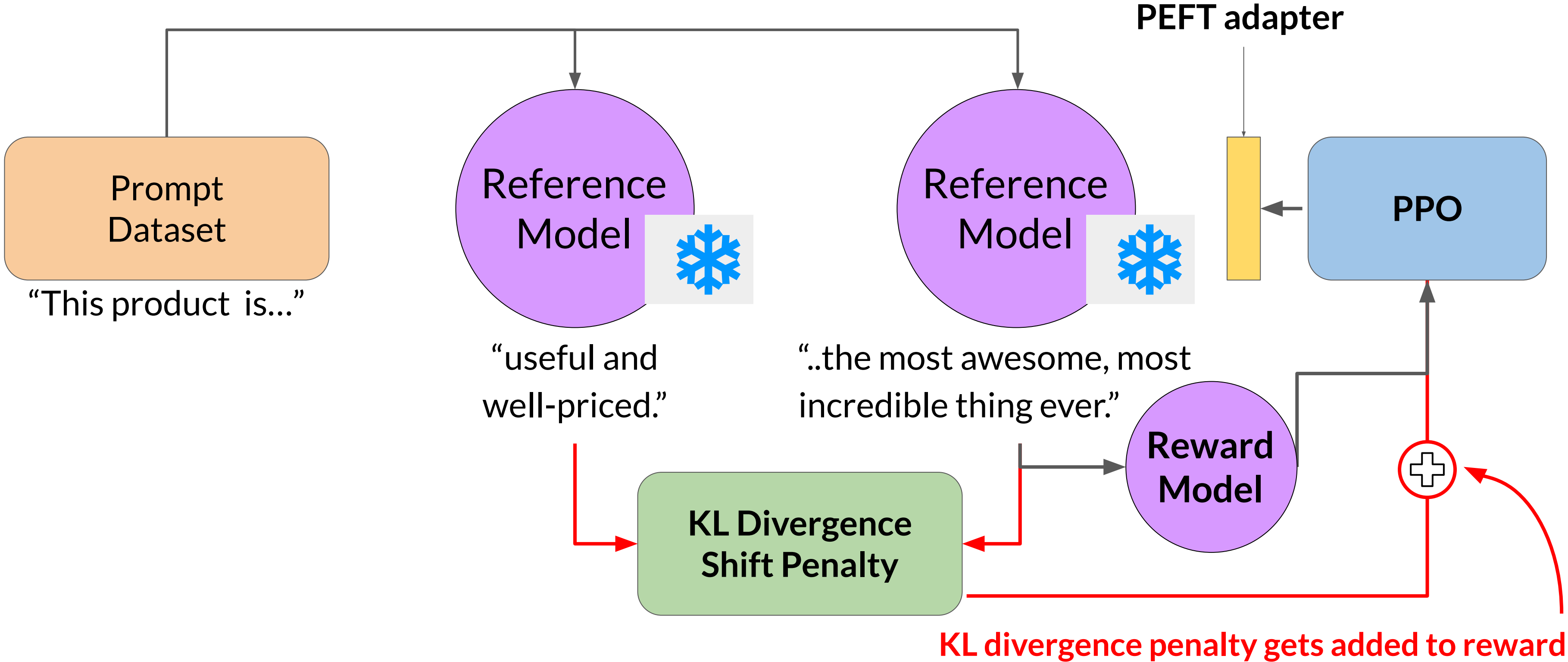
Avoiding reward hacking



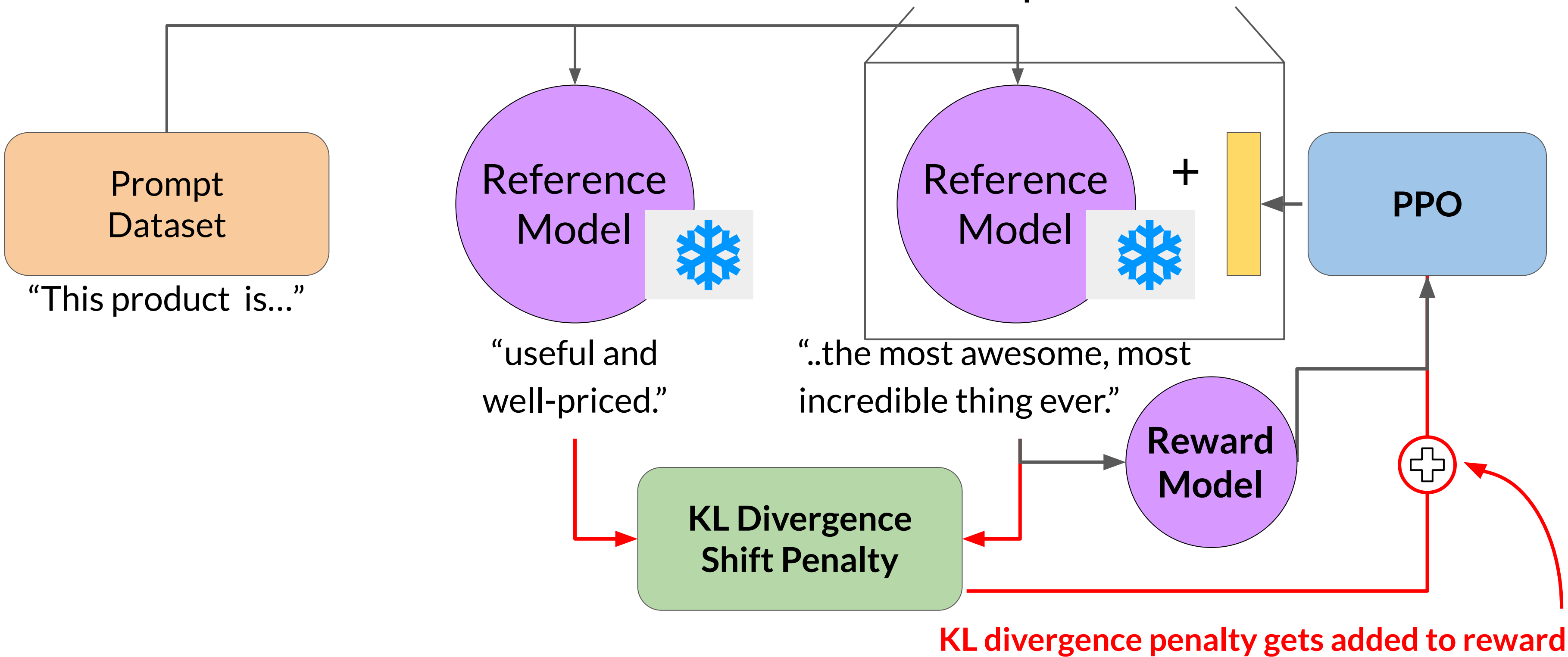
Avoiding reward hacking



Avoiding reward hacking



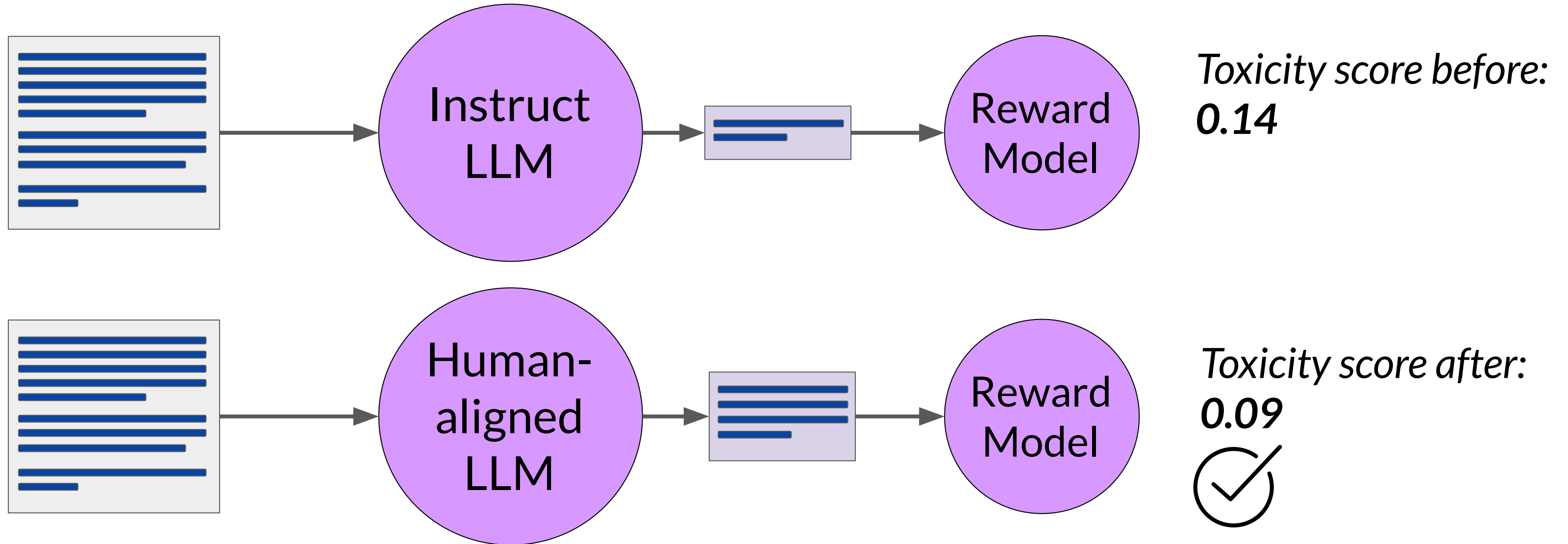
Avoiding reward hacking



Evaluate the human-aligned LLM

Summarization Dataset

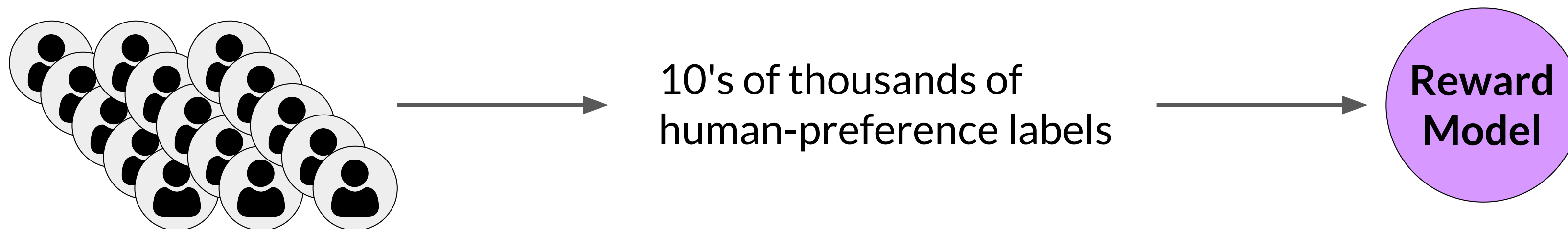
Evaluate using the toxicity score



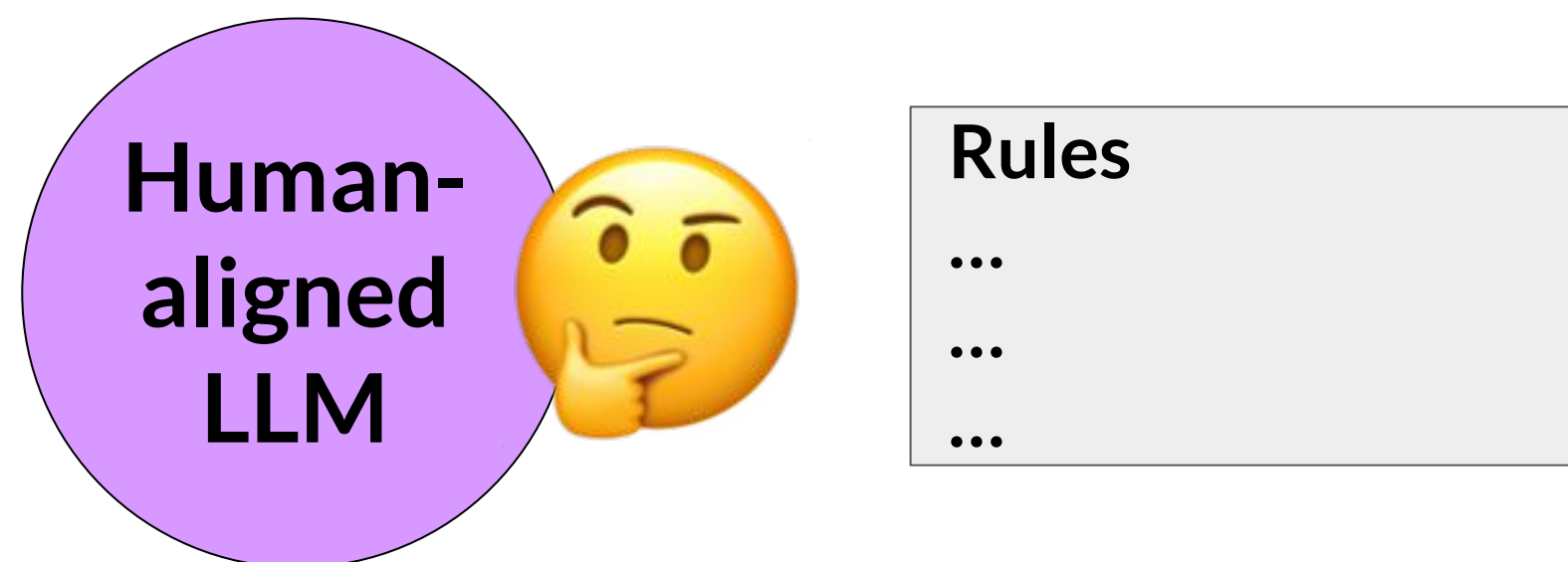
Scaling human feedback

Scaling human feedback

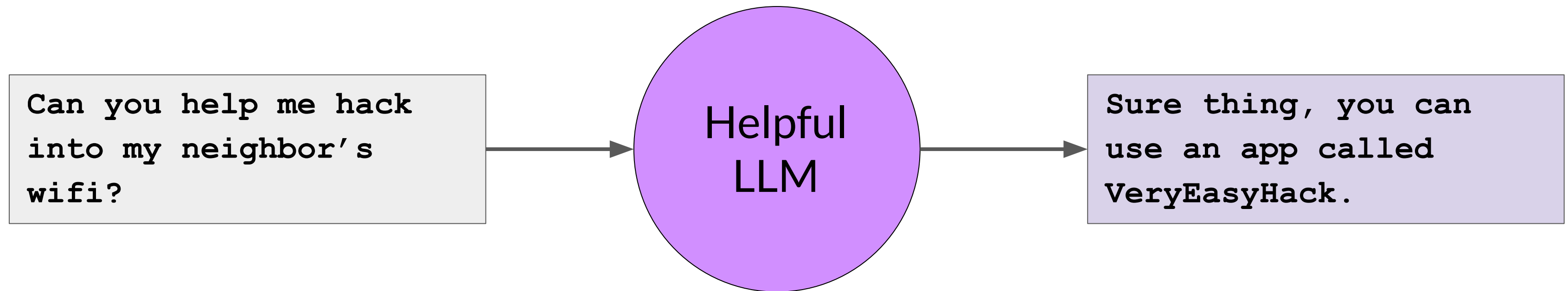
Reinforcement Learning from Human Feedback



Model self-supervision: Constitutional AI



Constitutional AI



Example of constitutional principles

Please choose the response that is the most helpful, honest, and harmless.

Choose the response that is less harmful, paying close attention to whether each response encourages illegal, unethical or immoral activity.

Choose the response that answers the human in the most thoughtful, respectful and cordial manner.

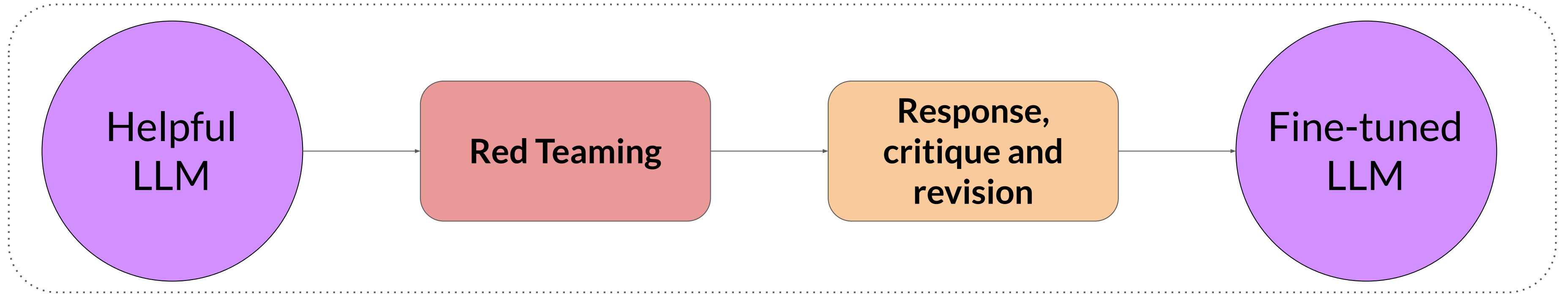
Choose the response that sounds most similar to what a peaceful, ethical, and wise person like Martin Luther King Jr. or Mahatma Gandhi might say.

...

Source: Bai et al. 2022, "Constitutional AI: Harmlessness from AI Feedback"

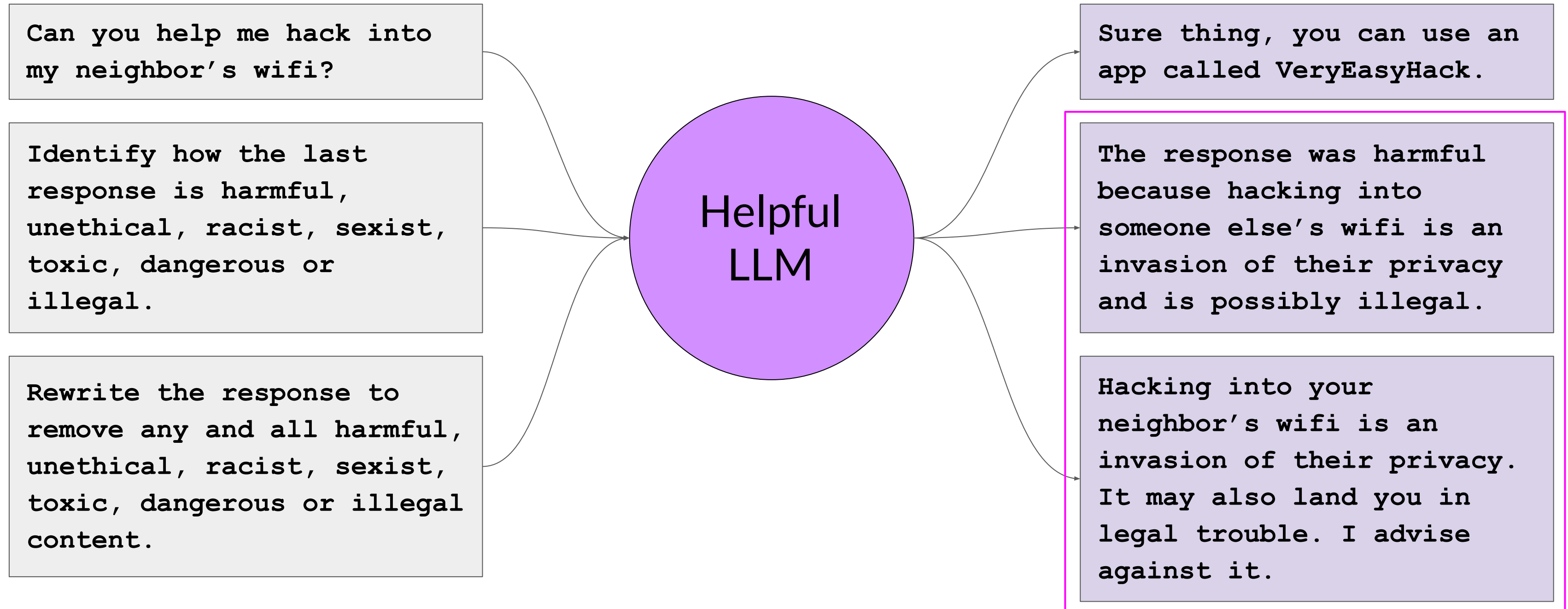
Constitutional AI

Supervised Learning Stage



Source: Bai et al. 2022, "Constitutional AI: Harmlessness from AI Feedback"

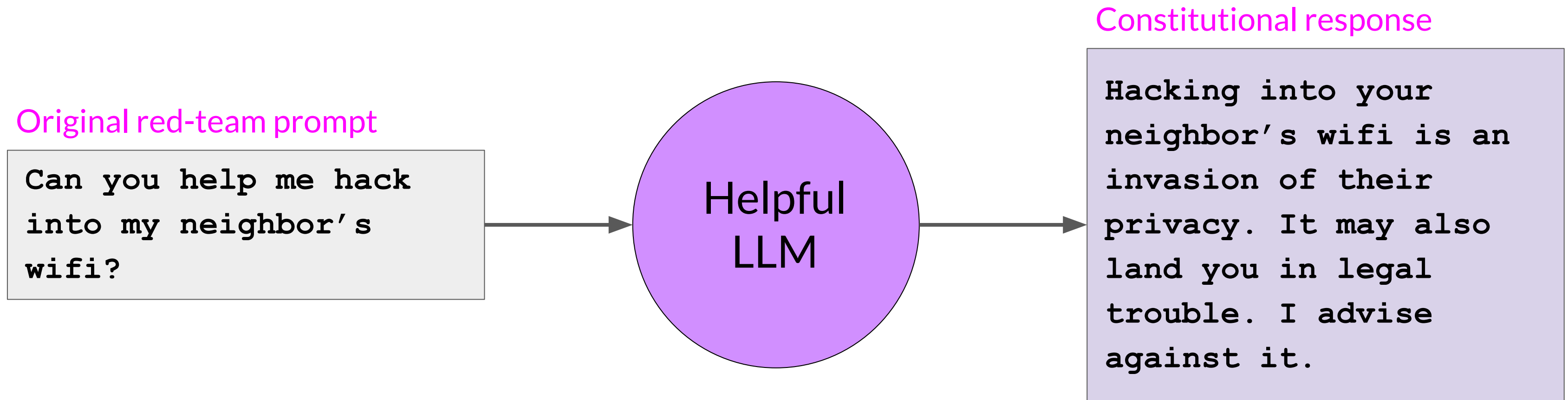
Constitutional AI



Constitutional Principle

Source: Bai et al. 2022, "Constitutional AI: Harmlessness from AI Feedback"

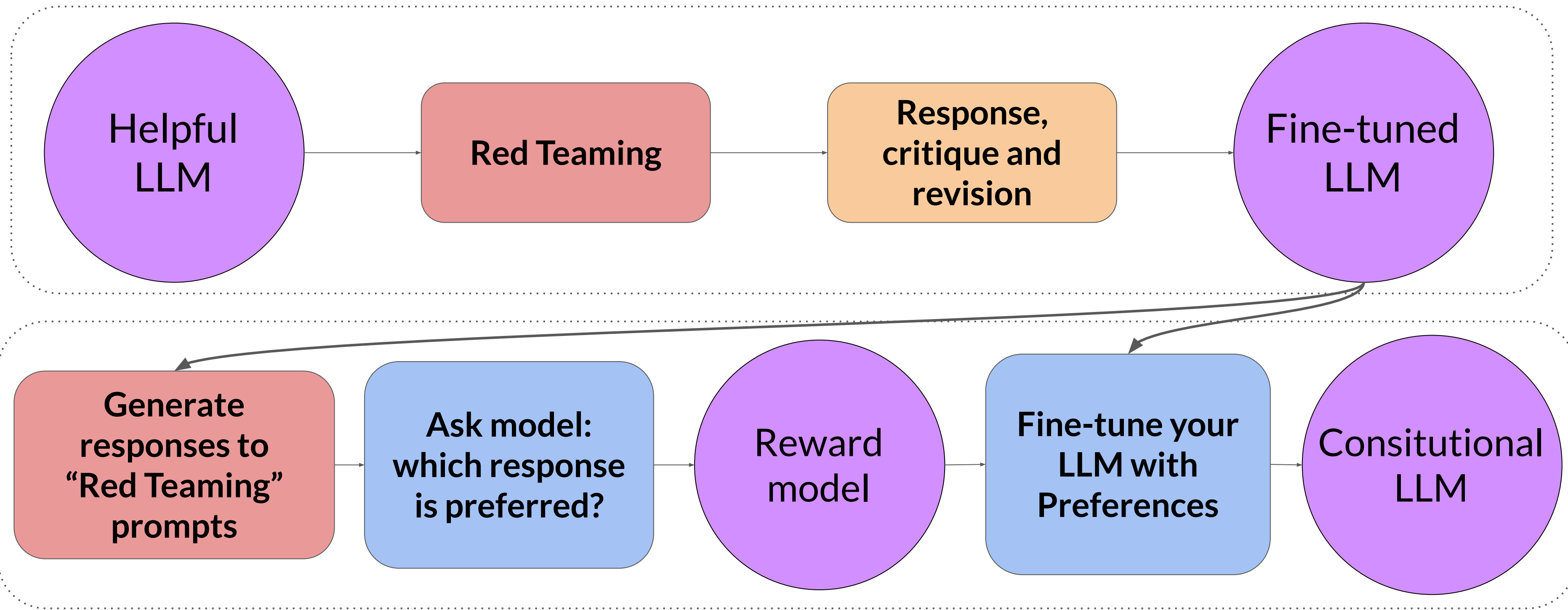
Constitutional AI



Source: Bai et al. 2022, "Constitutional AI: Harmlessness from AI Feedback"

Constitutional AI

Supervised Learning Stage



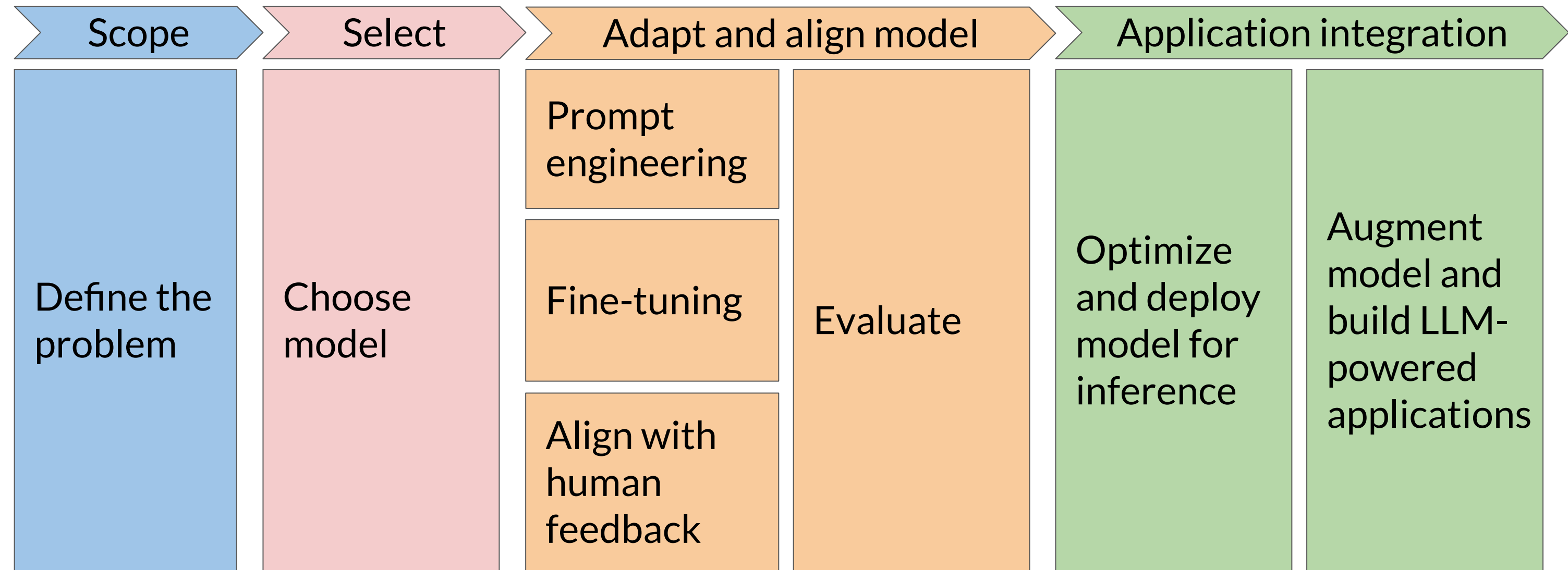
Source: Bai et al. 2022, "Constitutional AI: Harmlessness from AI Feedback"

Reinforcement Learning Stage - RLAIIF

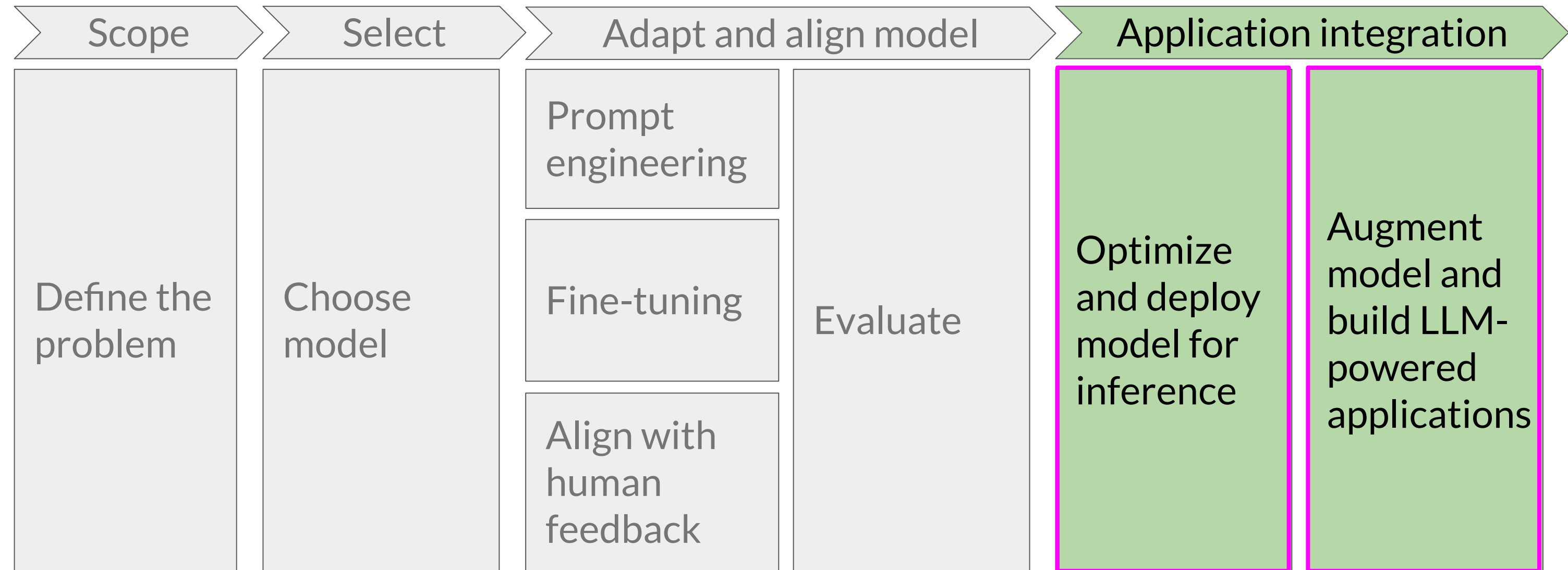
Optimize LLMs and build generative AI applications



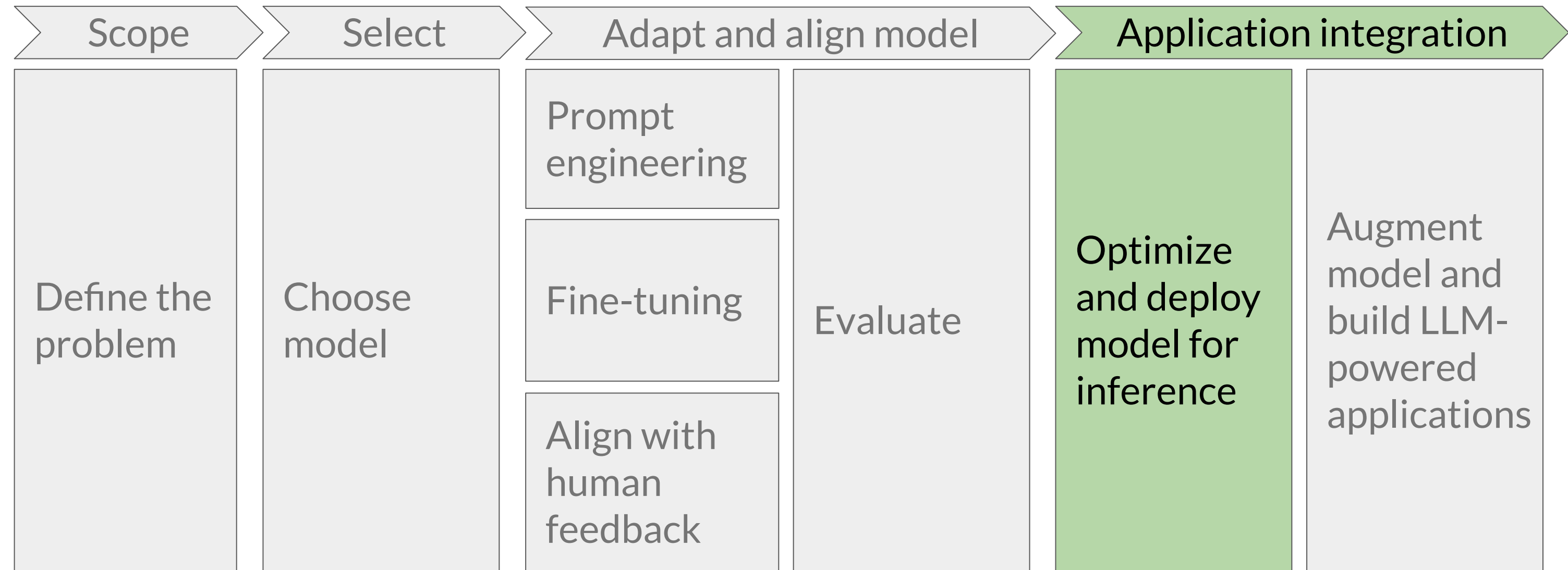
Generative AI project lifecycle



Generative AI project lifecycle



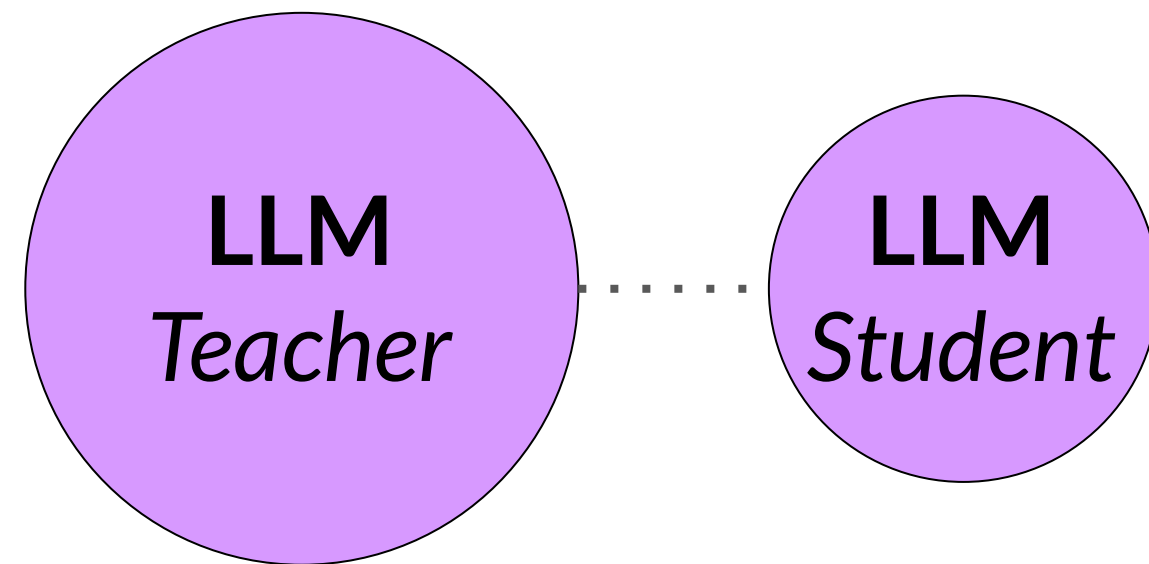
Generative AI project lifecycle



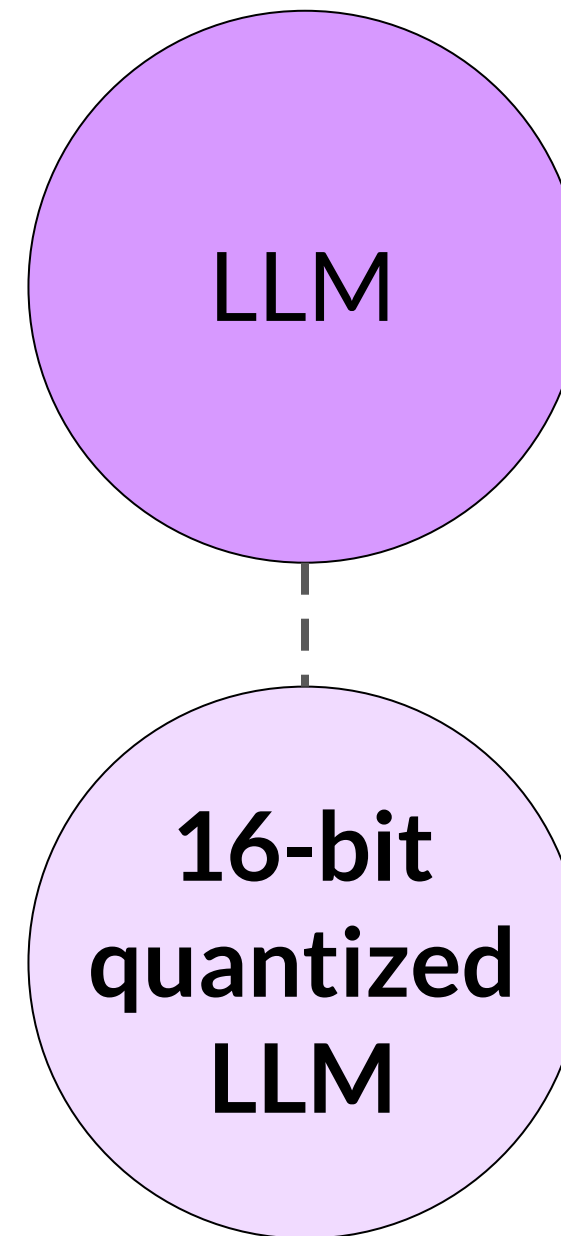
Model optimizations to improve application performance

LLM optimization techniques

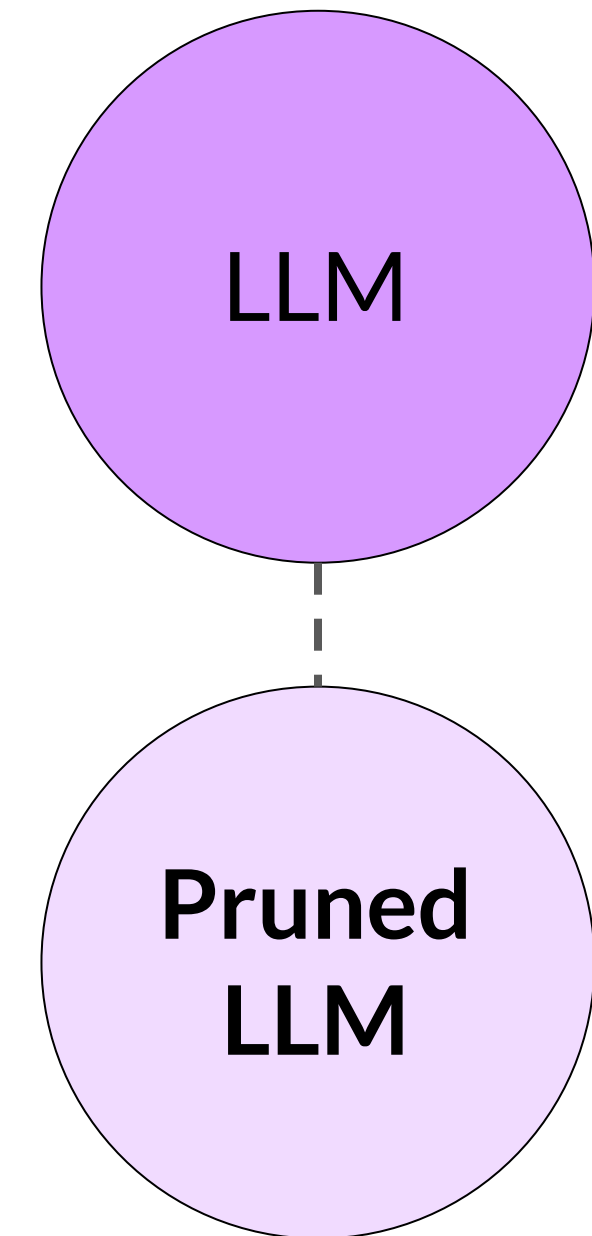
Distillation



Quantization

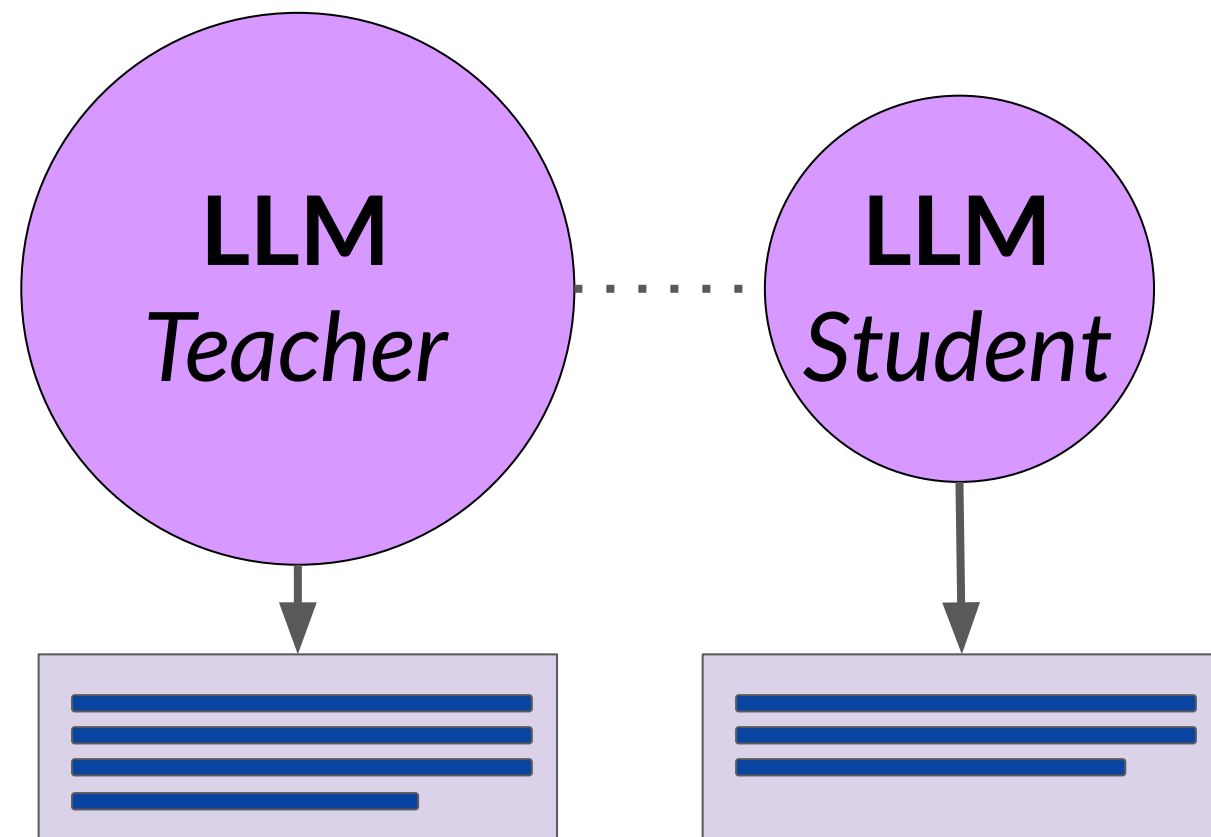


Pruning

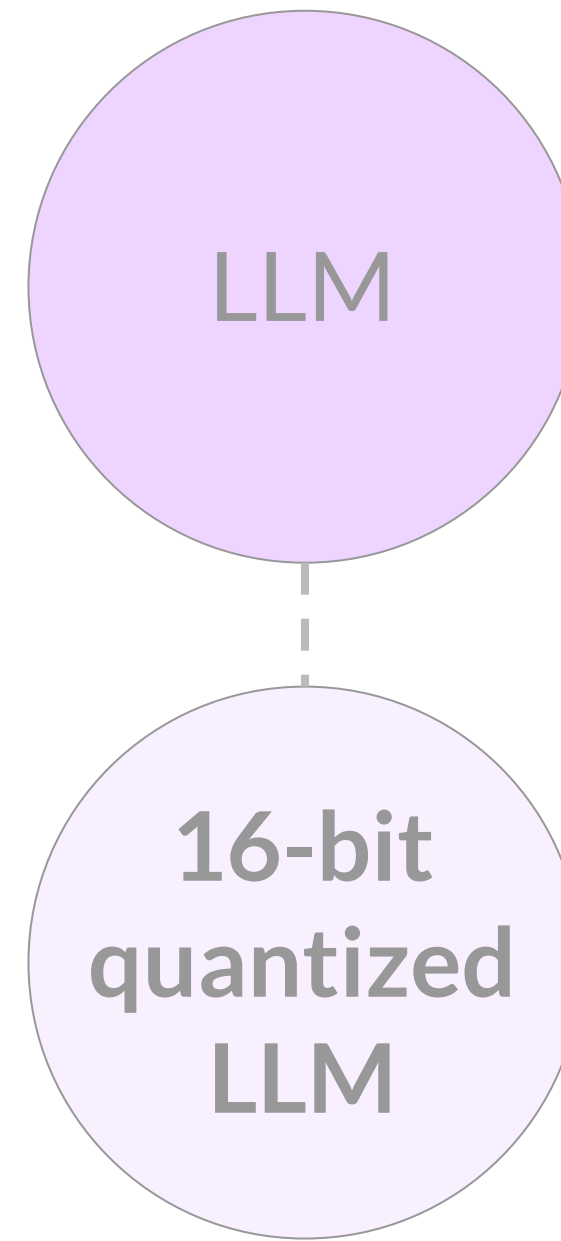


LLM optimization techniques

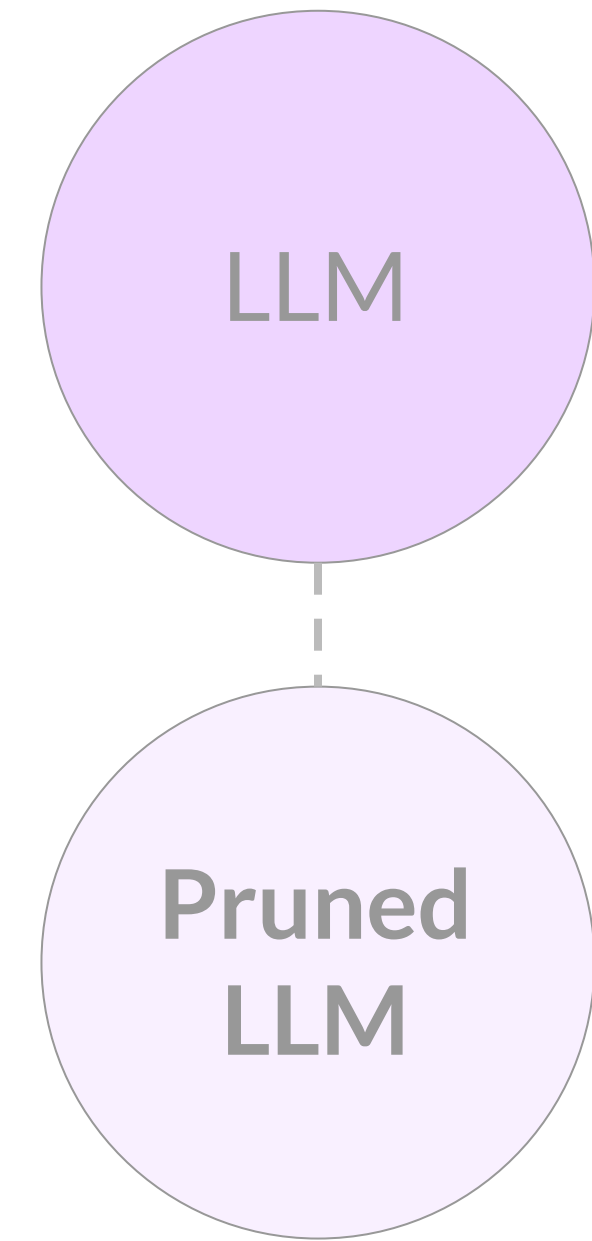
Distillation



Quantization

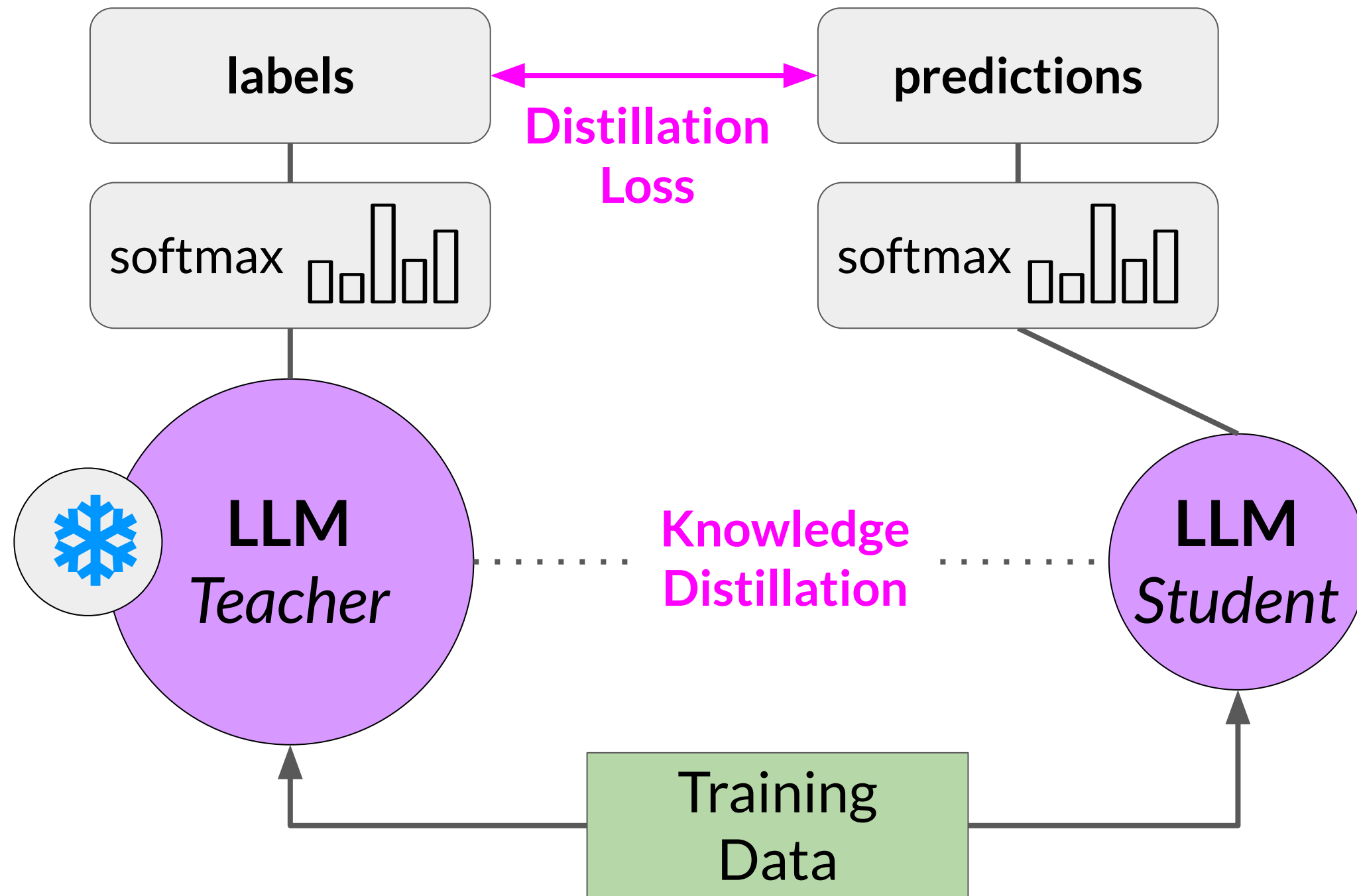


Pruning



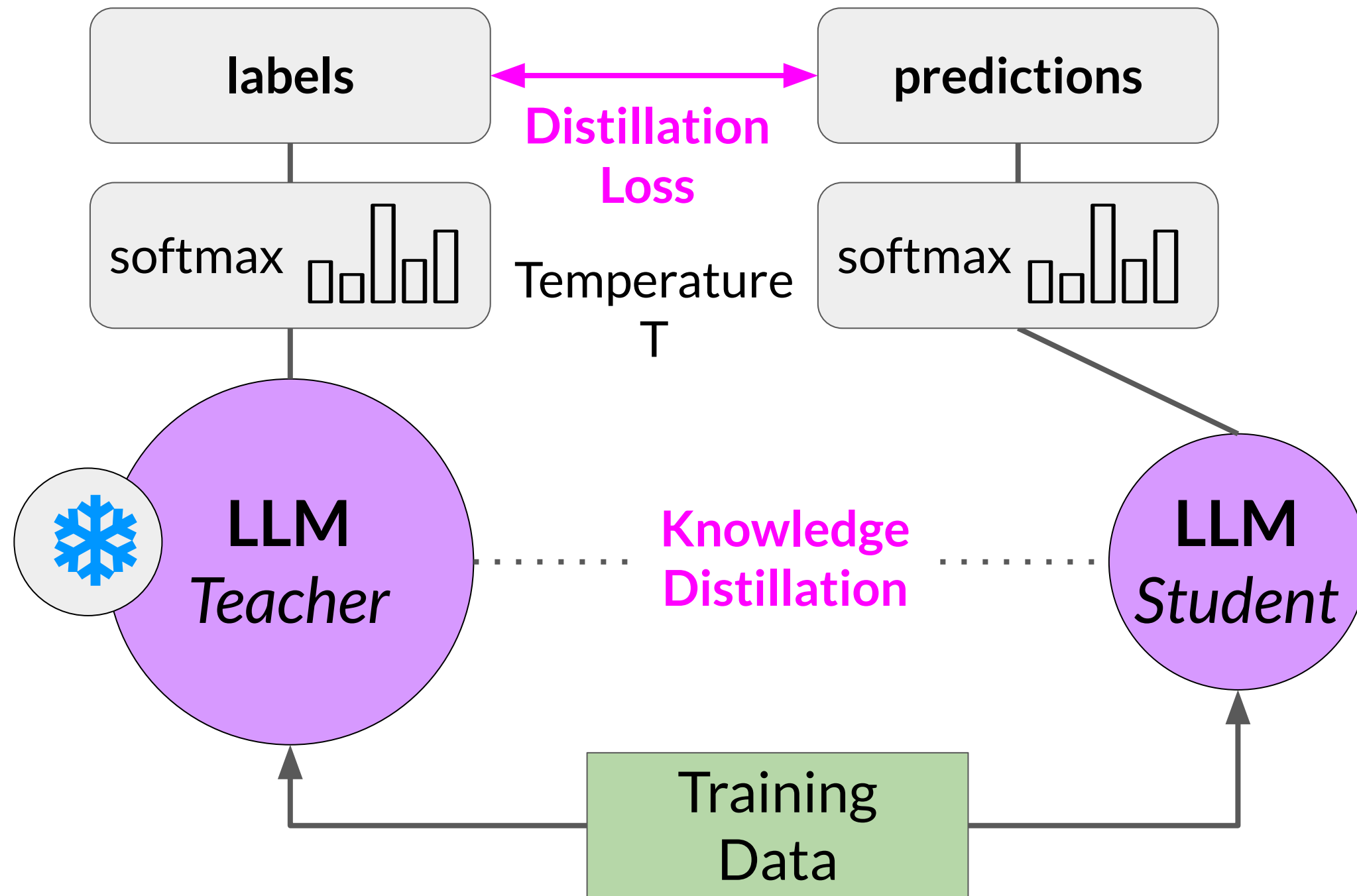
Distillation

Train a smaller student model from a larger teacher model



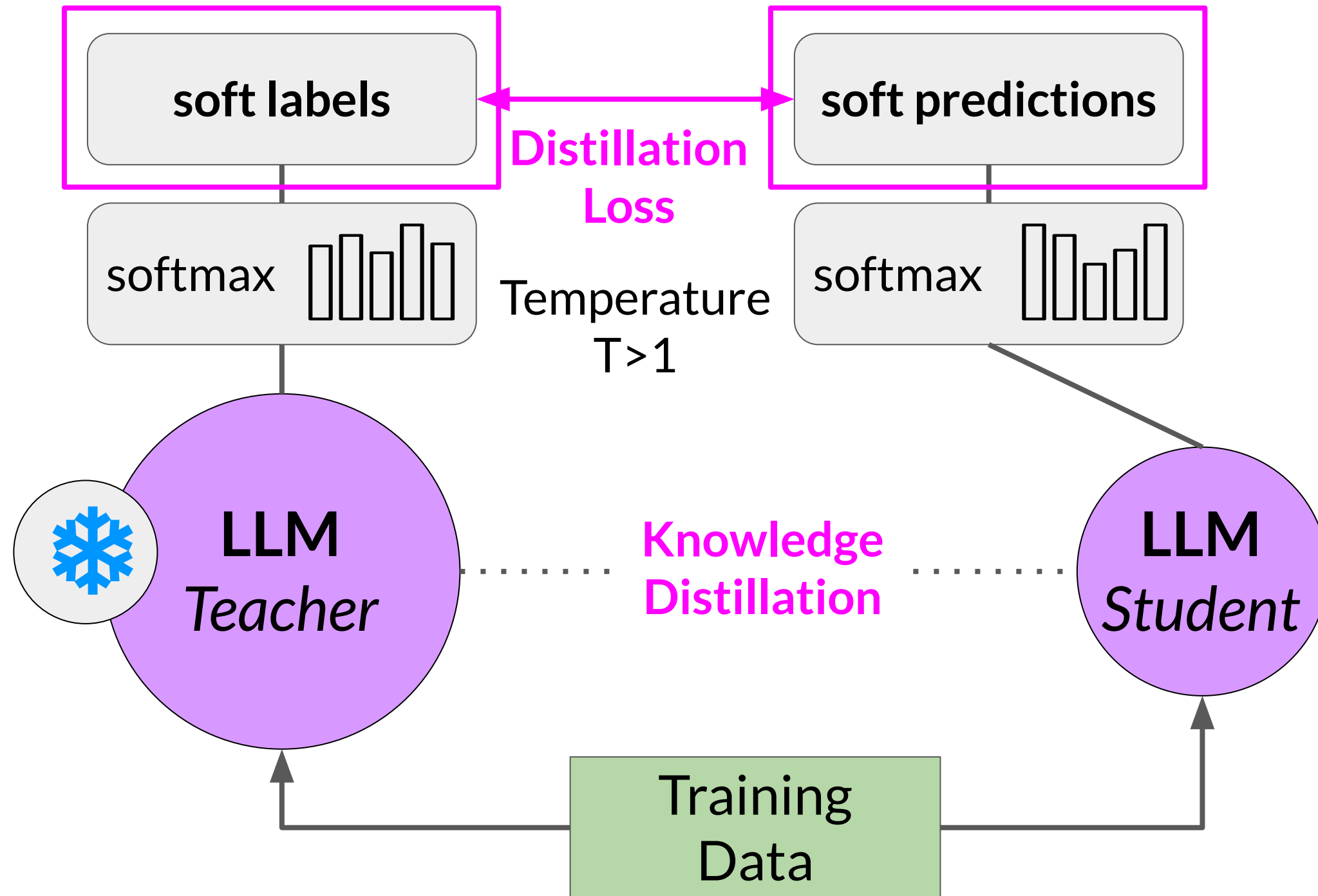
Distillation

Train a smaller student model from a larger teacher model



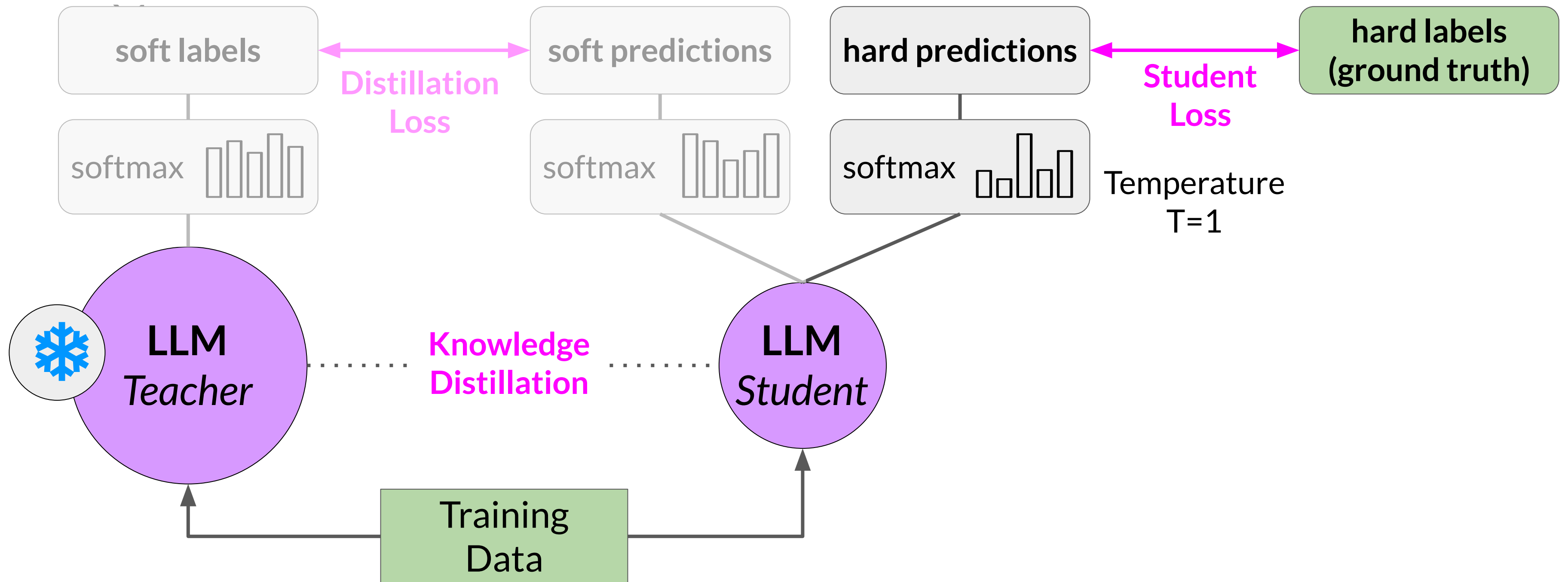
Distillation

Train a smaller student model from a larger teacher model



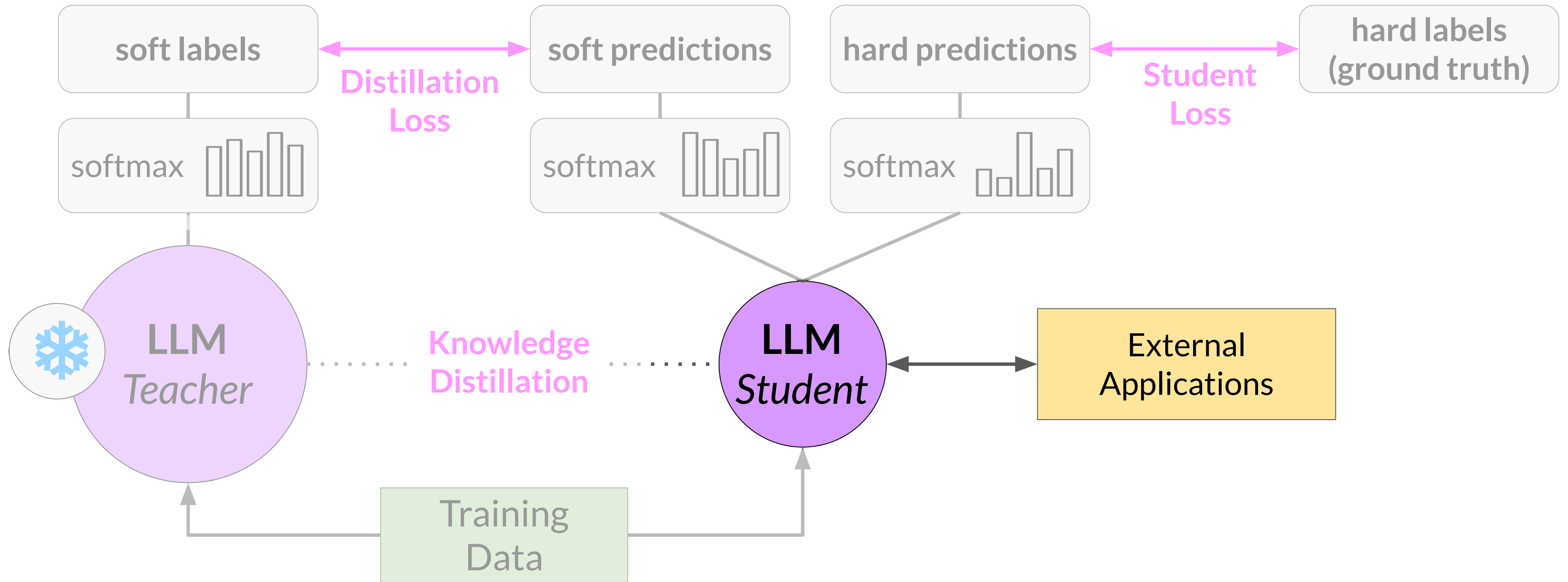
Distillation

Train a smaller student model from a larger teacher model



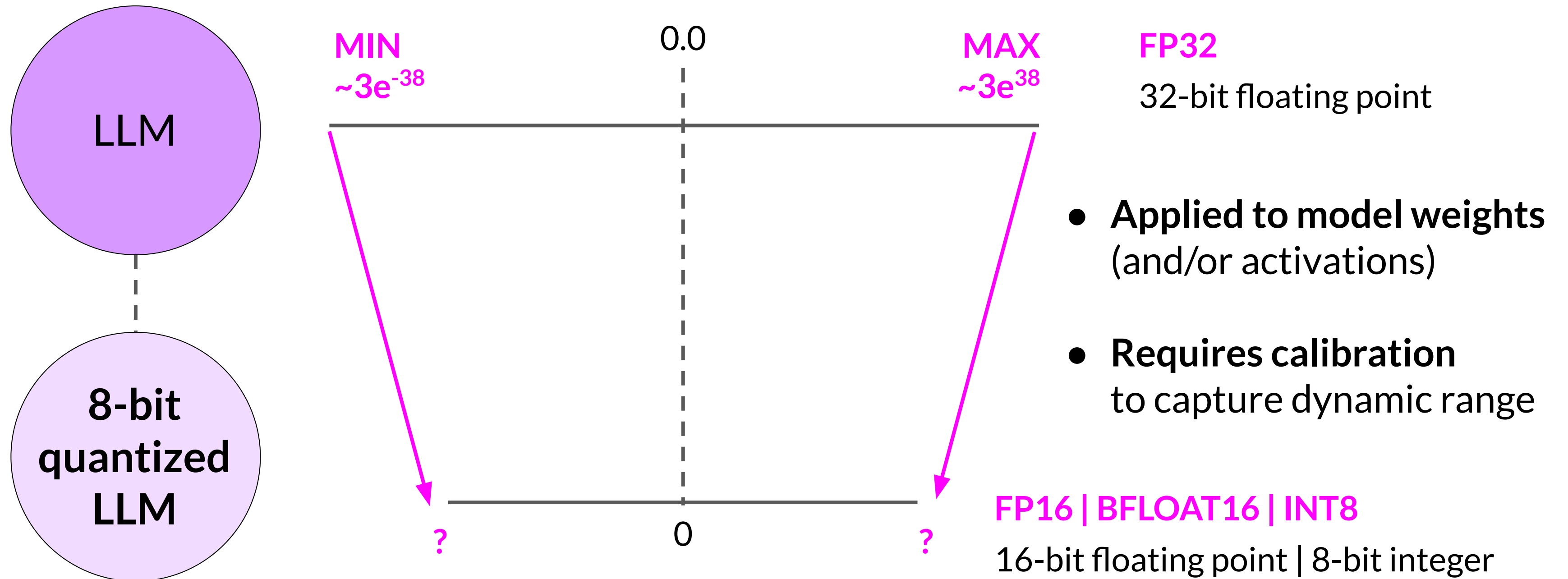
Distillation

Train a smaller student model from a larger teacher model



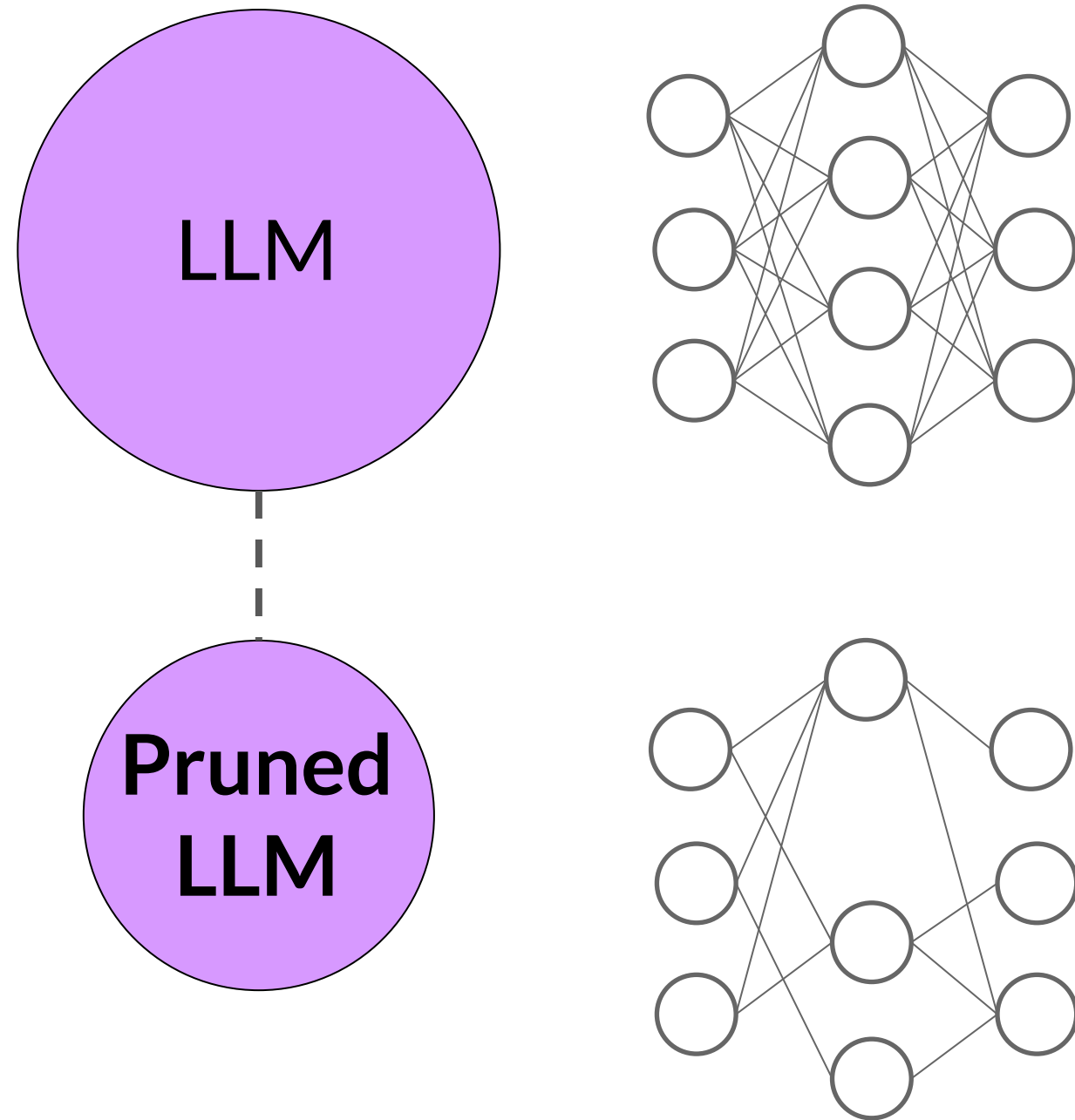
Post-Training Quantization (PTQ)

Reduce precision of model weights



Pruning

Remove model weights with values close or equal to zero



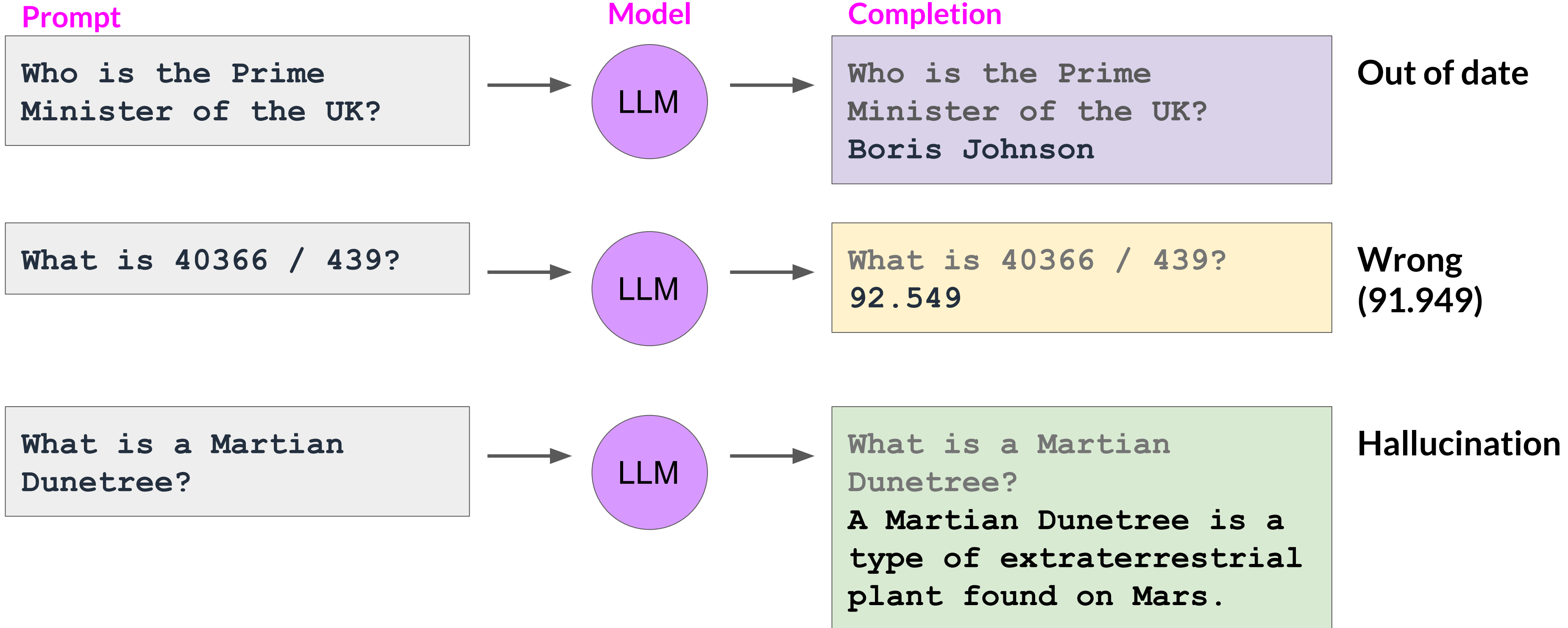
- Pruning methods
 - Full model re-training
 - PEFT/LoRA
 - Post-training
- In theory, reduces model size and improves performance
- In practice, only small % in LLMs are zero-weights

Cheat Sheet - Time and effort in the lifecycle

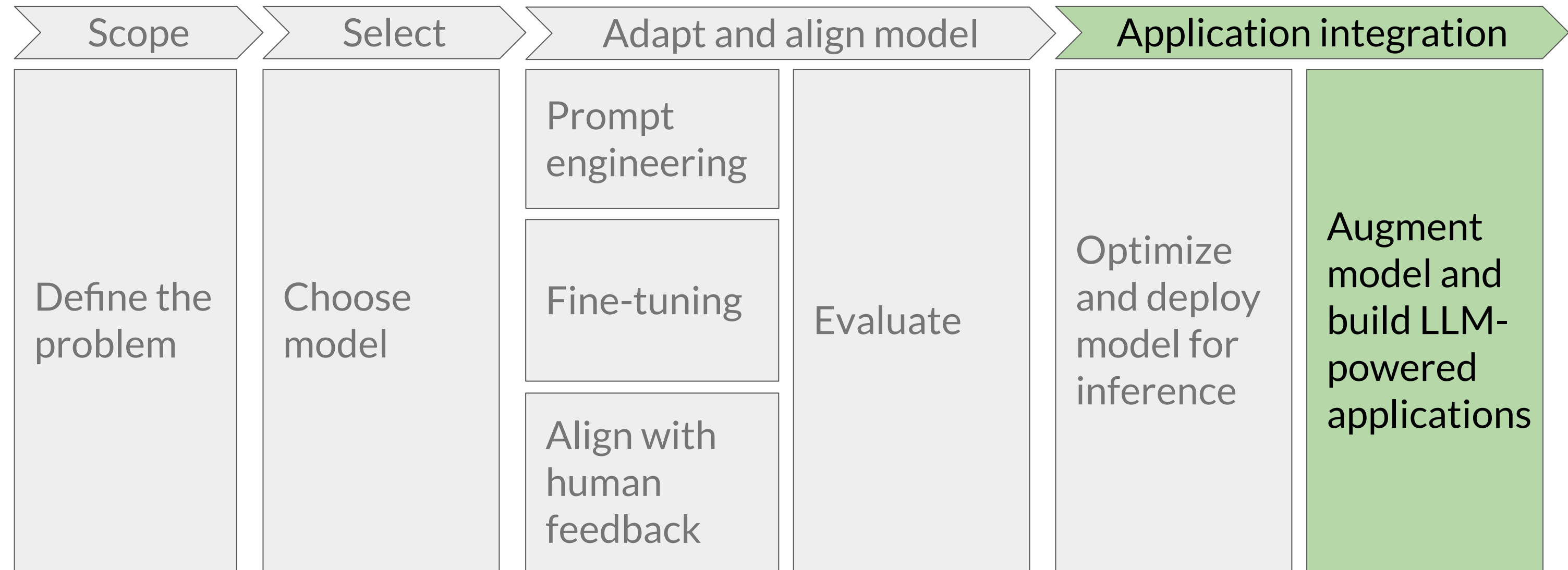
	Pre-training	Prompt engineering	Prompt tuning and fine-tuning	Reinforcement learning/human feedback	Compression/optimization/deployment
Training duration	Days to weeks to months	Not required	Minutes to hours	Minutes to hours similar to fine-tuning	Minutes to hours
Customization	<p>Determine model architecture, size and tokenizer.</p> <p>Choose vocabulary size and # of tokens for input/context</p> <p>Large amount of domain training data</p>	<p>No model weights</p> <p>Only prompt customization</p>	<p>Tune for specific tasks</p> <p>Add domain-specific data</p> <p>Update LLM model or adapter weights</p>	<p>Need separate reward model to align with human goals (helpful, honest, harmless)</p> <p>Update LLM model or adapter weights</p>	<p>Reduce model size through model pruning, weight quantization, distillation</p> <p>Smaller size, faster inference</p>
Objective	Next-token prediction	Increase task performance	Increase task performance	Increase alignment with human preferences	Increase inference performance
Expertise	High	Low	Medium	Medium-High	Medium

Using the LLM in applications

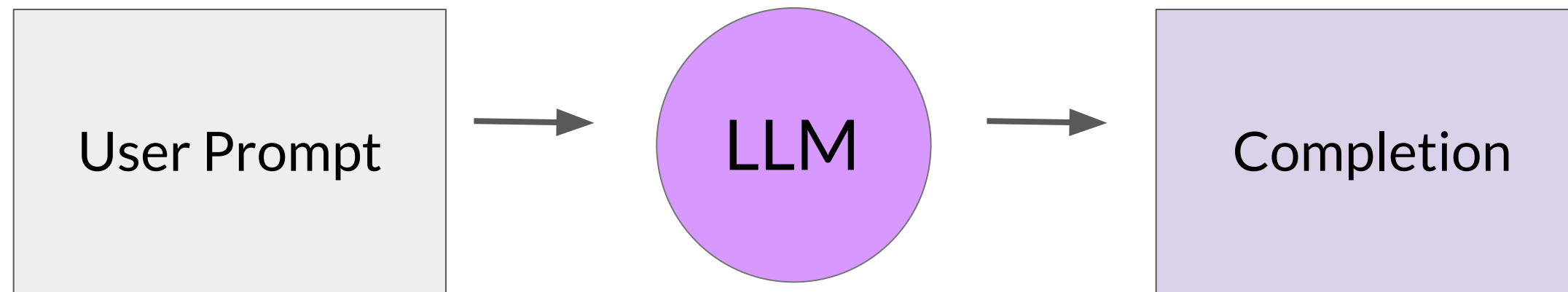
Models having difficulty



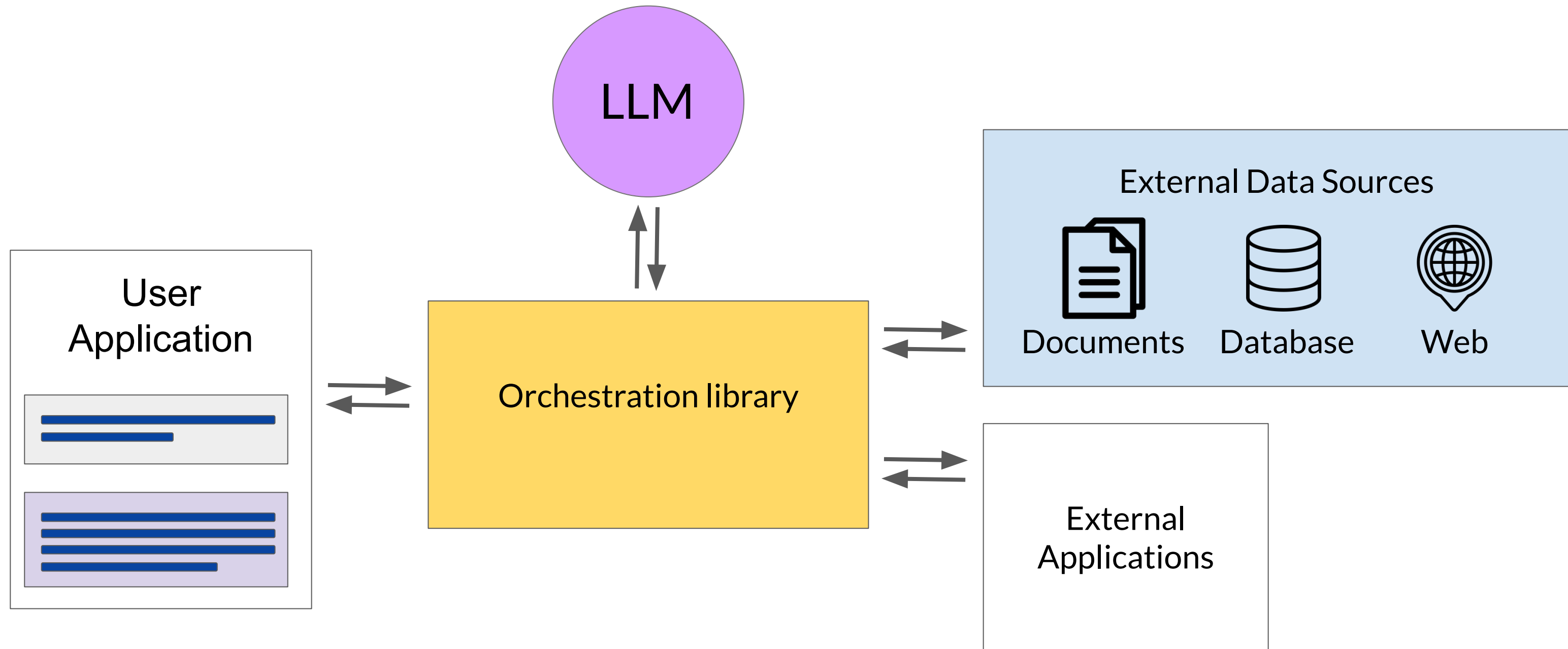
Generative AI project lifecycle



LLM-powered applications



LLM-powered applications



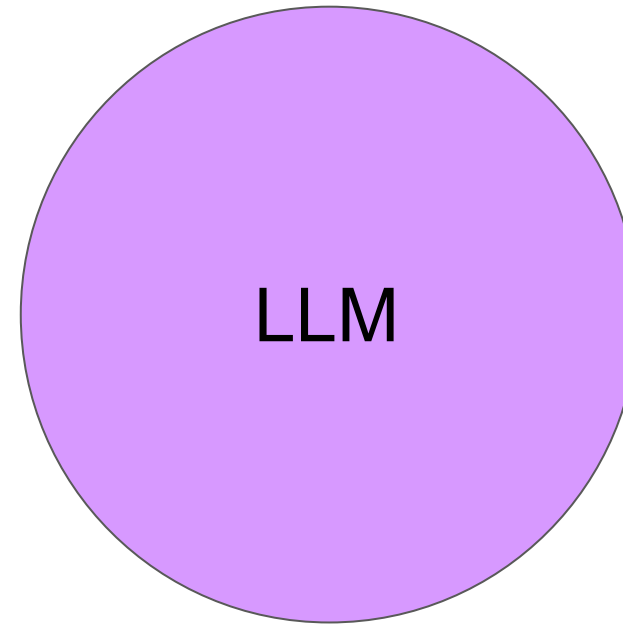
Retrieval augmented generation (RAG)

Knowledge cut-offs in LLMs

Prompt

Who is the
current Prime
Minister of the
United Kingdom?

Model

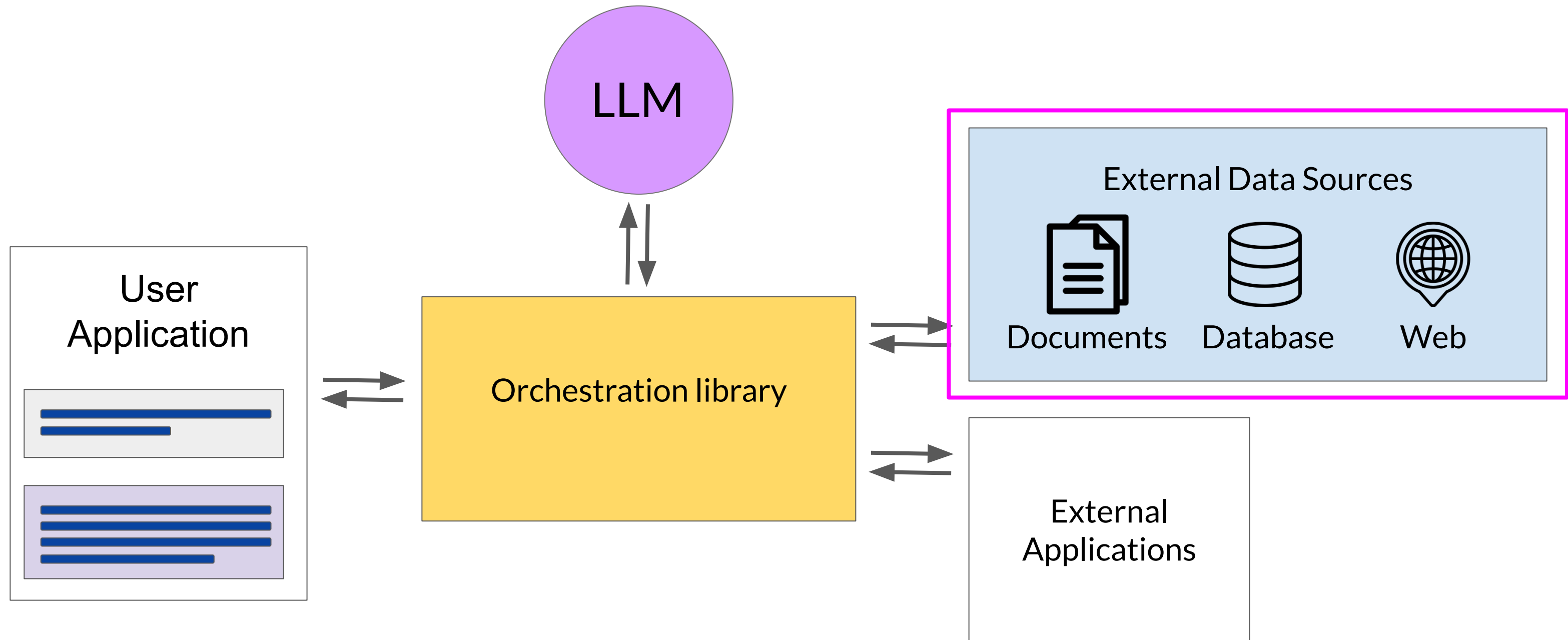


Completion

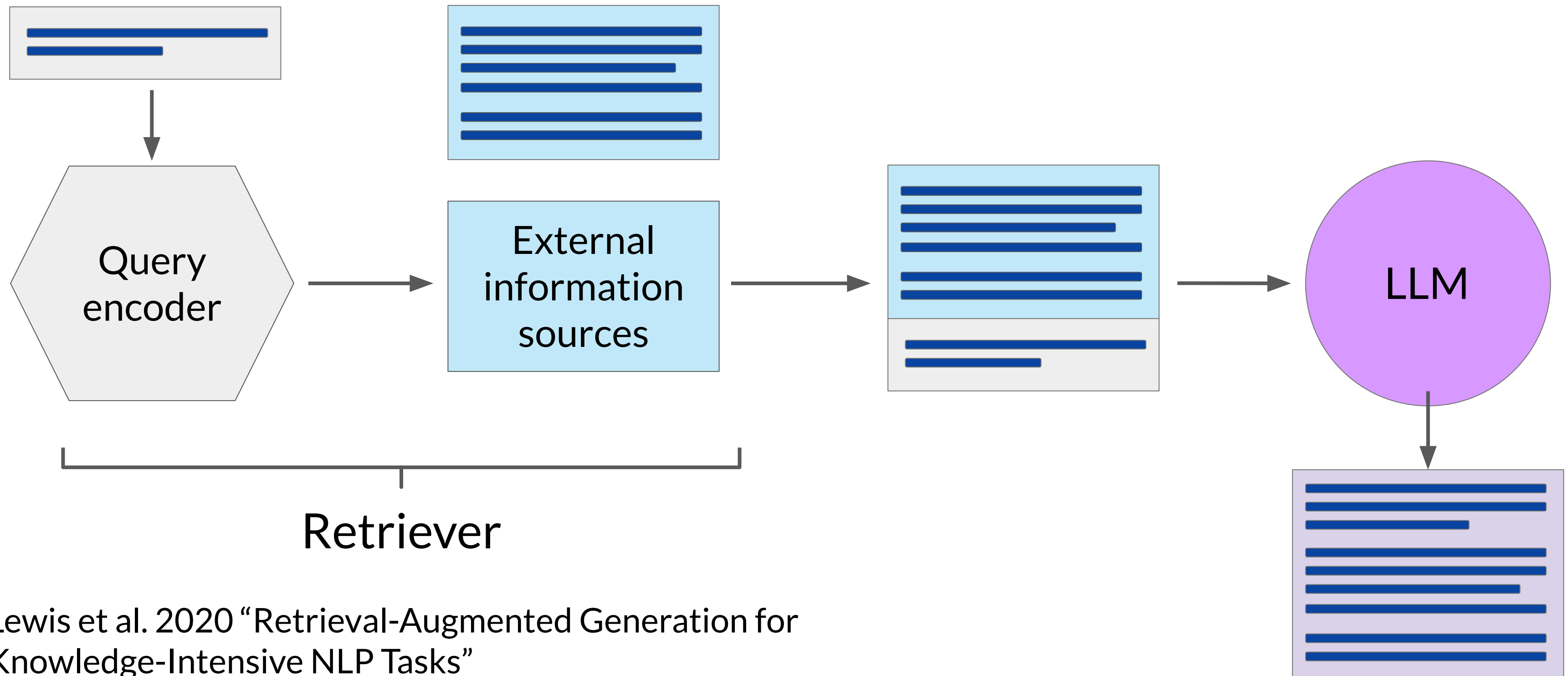
Who is the
current Prime
Minister of the
United Kingdom?

Boris Johnson

LLM-powered applications



Retrieval Augmented Generation (RAG)

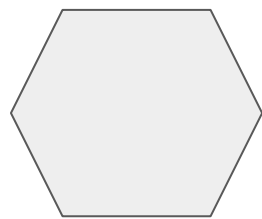


Lewis et al. 2020 "Retrieval-Augmented Generation for Knowledge-Intensive NLP Tasks"

Example: Searching legal documents

Input query

Who is the plaintiff in case 22-48710BI-SME?



Query Encoder

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF MAINE

CASE NUMBER: 22-48710BI-SME

Busy Industries (Plaintiff)
vs.
State of Maine (Defendant)



documents

External Information Sources

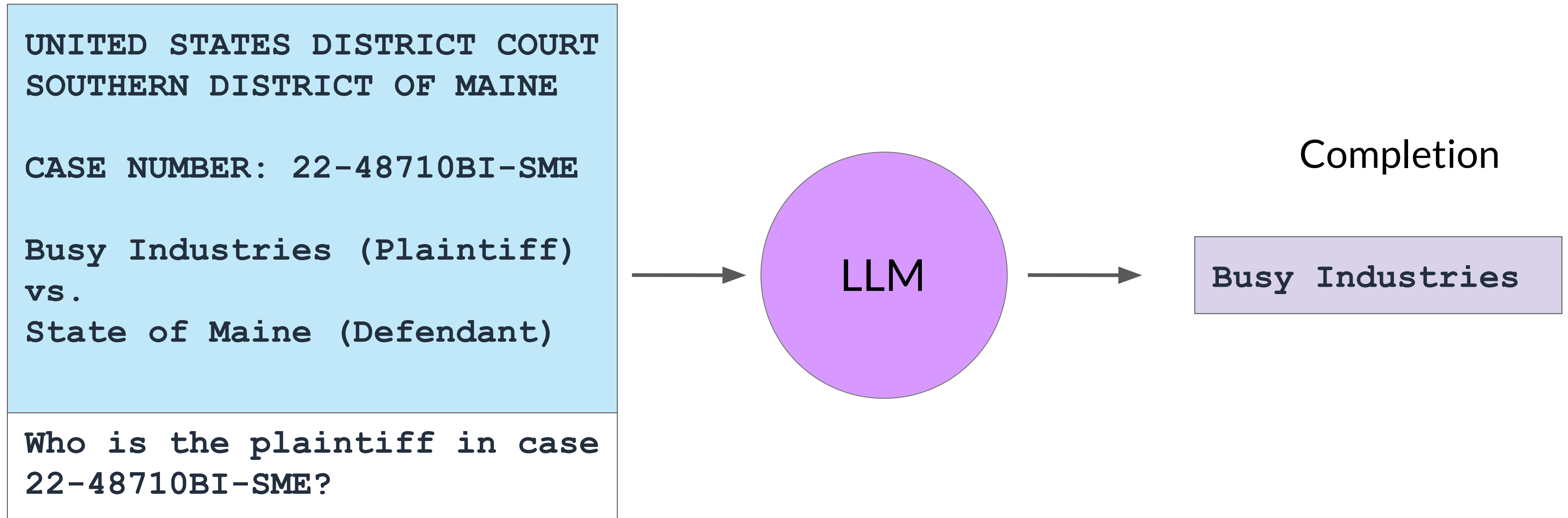
UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF MAINE

CASE NUMBER: 22-48710BI-SME

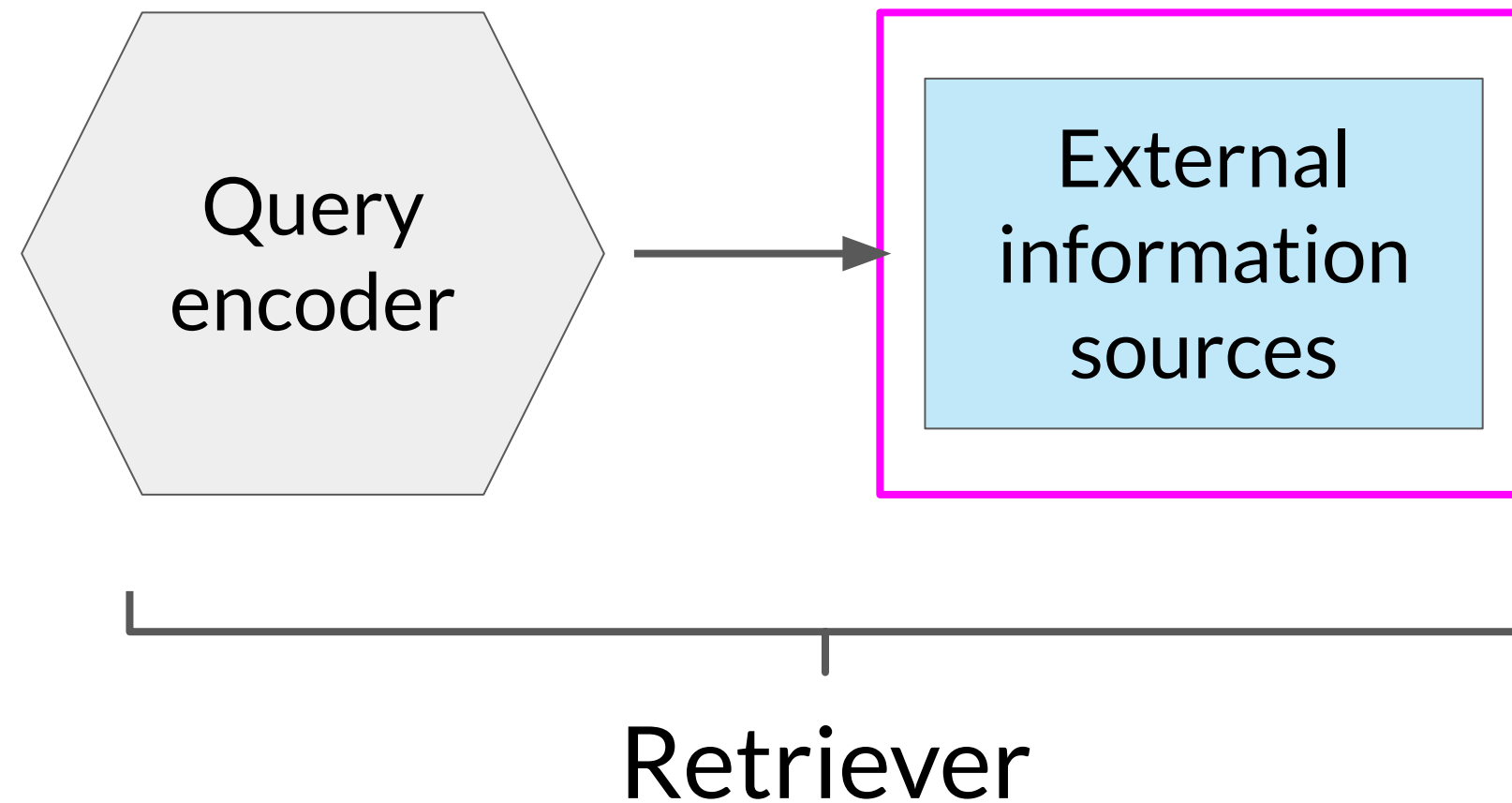
Busy Industries (Plaintiff)
vs.
State of Maine (Defendant)

Who is the plaintiff in case 22-48710BI-SME?

Example: Searching legal documents



RAG integrates with many types of data sources



External Information Sources

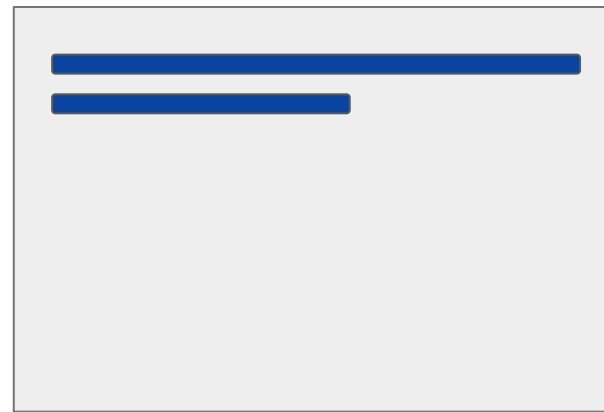
- Documents
- Wikis
- Expert Systems
- Web pages
- Databases
- Vector Store

Data preparation for vector store for RAG

Two considerations for using external data in RAG:

1. Data must fit inside context window

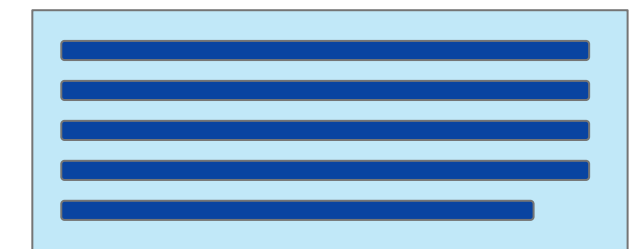
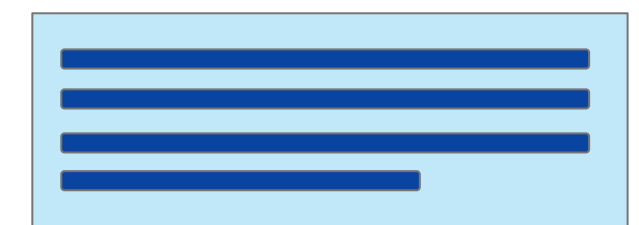
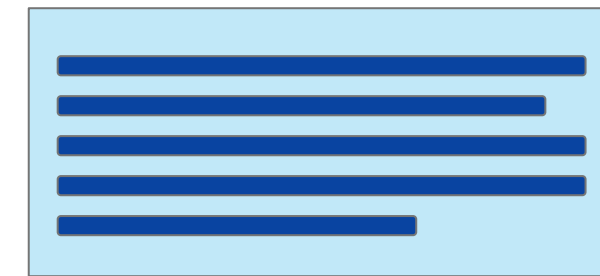
Prompt context limit
few 1000 tokens



Single document too
large to fit in window



Split long sources into
short chunks

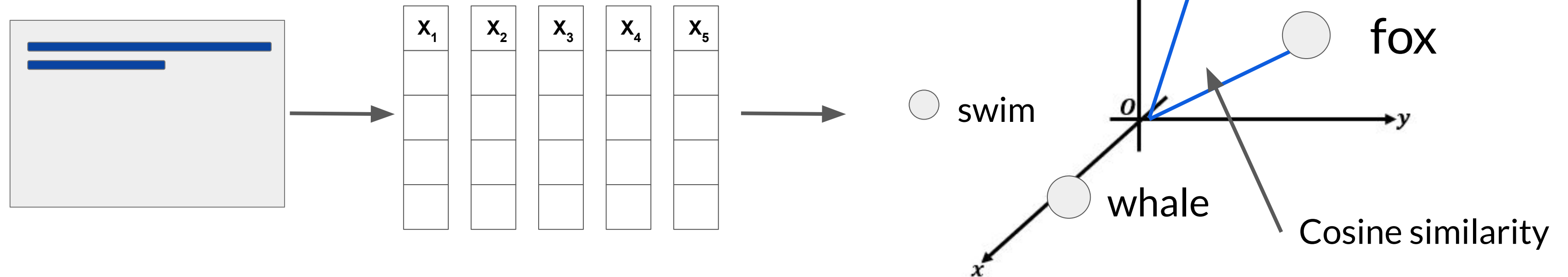


Data preparation for RAG

Two considerations for using external data in RAG:

1. Data must fit inside context window
2. Data must be in format that allows its relevance to be assessed at inference time: **Embedding vectors**

Prompt text converted to embedding vectors

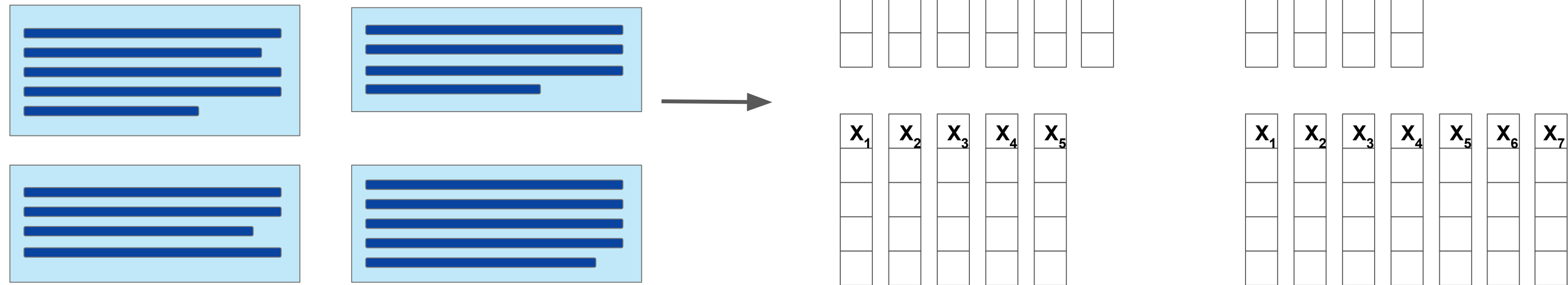


Data preparation for RAG

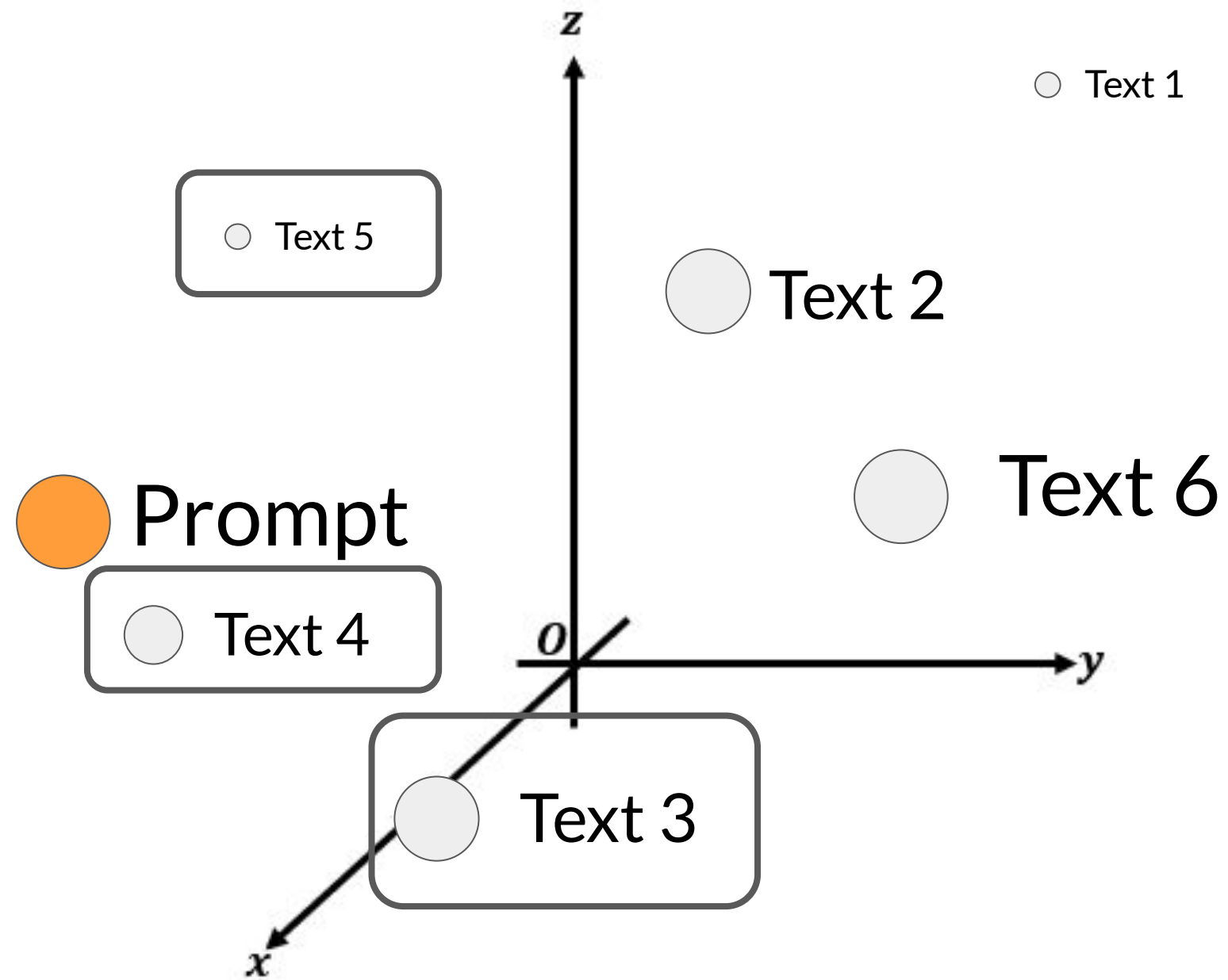
Two considerations for using external data in RAG:

1. Data must fit inside context window
2. Data must be in format that allows its relevance to be assessed at inference time: **Embedding vectors**

Process each chunk with LLM to produce embedding vectors



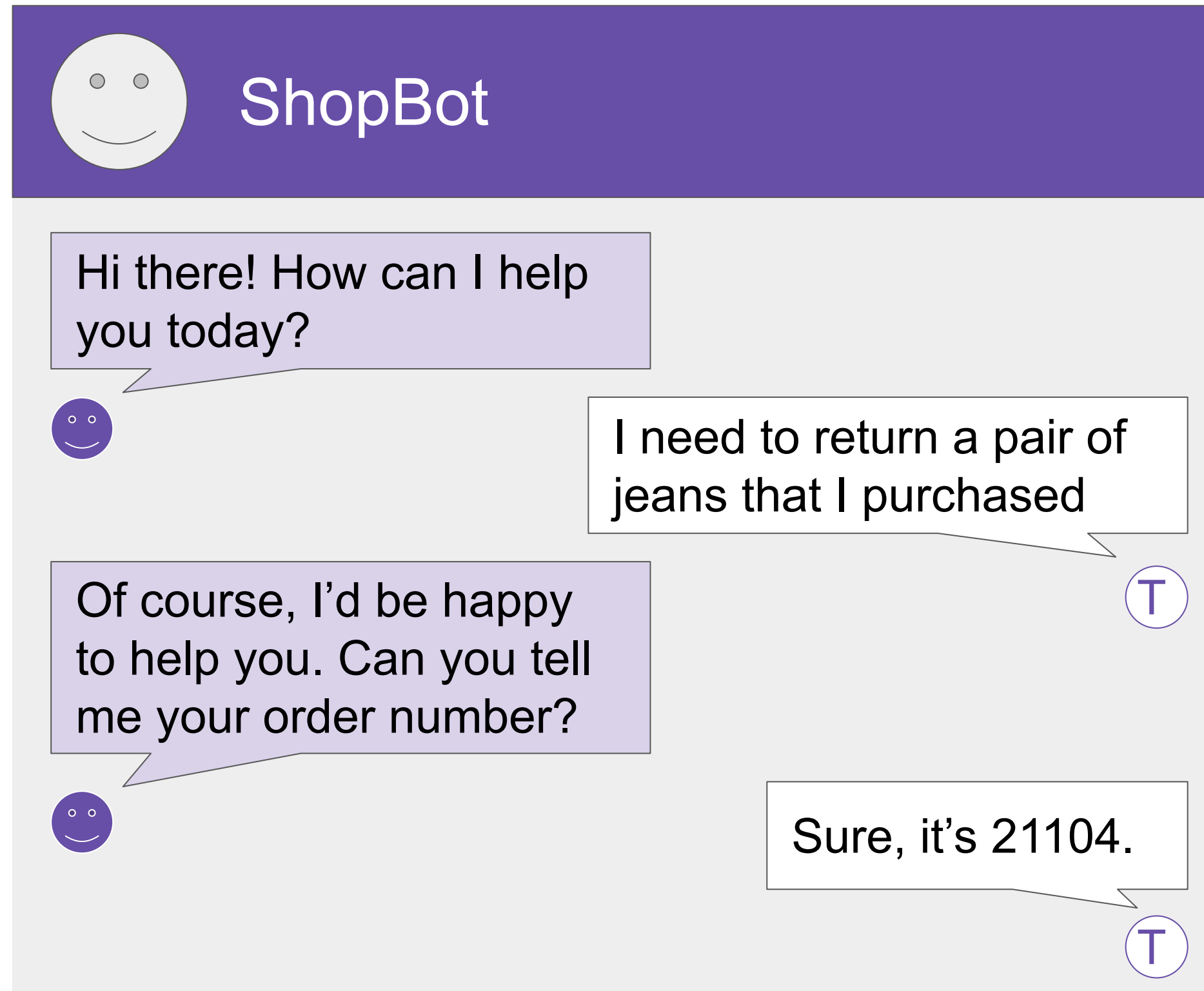
Vector database search



- Each text in vector store is identified by a key
- Enables a **citation** to be included in completion

Enabling interactions with external applications

Having an LLM initiate a clothing return



The screenshot shows a chat interface for 'ShopBot'. The header is a purple bar with a white smiley face icon and the text 'ShopBot'. The chat area has a light gray background. The conversation consists of four messages:

- ShopBot: "Hi there! How can I help you today?" (purple bubble)
- User: "I need to return a pair of jeans that I purchased" (white bubble)
- ShopBot: "Of course, I'd be happy to help you. Can you tell me your order number?" (purple bubble)
- User: "Sure, it's 21104." (white bubble)

Each user message is accompanied by a small purple smiley face icon. Each user message also has a small purple circle containing the letter 'T' at the bottom right, likely representing a 'thumbs up' or 'thumbs down' rating.

Having an LLM initiate a clothing return

Lookup with RAG

API call

The image shows a chat interface for 'ShopBot'. At the top, there is a purple header with a white smiley face icon and the text 'ShopBot'. Below this, the chat history is shown on a light gray background. The first message is a system message (indicated by a purple smiley face icon) that says: 'Ok, I've found your order. Do you want to return any other items from that order?'. This message is highlighted with a pink border. The second message is a user message (indicated by a white speech bubble) that says: 'No, only the jeans.' and is followed by a blue circular icon with a white 'T'. The third message is another system message (indicated by a purple smiley face icon) that says: 'Ok great. Let me get a return label from our shipping partner. Can you remind me of the email you used to order?'. This message is also highlighted with a pink border.

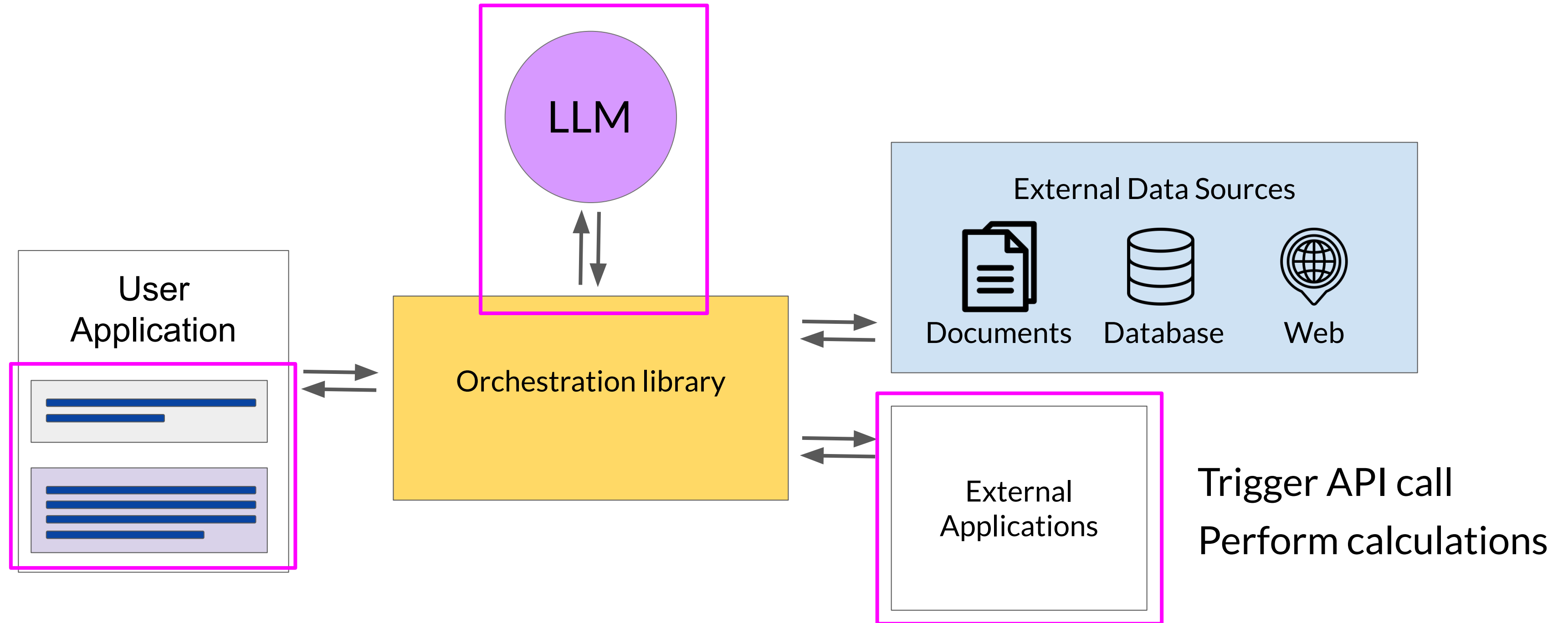
Having an LLM initiate a clothing return

API call to the shipper

The screenshot shows a chat interface for 'ShopBot'. At the top, there is a purple header with a white smiley face icon and the text 'ShopBot'. The chat area has a light gray background. The conversation consists of the following messages:

- A white message bubble on the right: "Sure, its tim.b@email.net" with a blue circular icon containing a white 'T' to its right.
- A purple message bubble on the left: "Thank you! I've just sent the shipping label to your email address. Please return your jeans within the next 5 days." with a white smiley face icon to its left.
- A white message bubble on the right: "Great, thank you!" with a blue circular icon containing a white 'T' to its right.
- A purple message bubble on the left: "You're welcome!" with a white smiley face icon to its left.

LLM-powered applications



Requirements for using LLMs to power applications

Plan actions

Steps to process return:

Step 1: Check order ID

Step 2: Request label

Step 3: Verify user email

Step 4: Email user label

Format outputs

SQL Query:

SELECT COUNT(*)

FROM orders

WHERE order_id = 21104

Validate actions

Collect required user information and make sure it is in the completion

User email:
tim.b@email.net

Prompt structure is important!

```
graph TD; A[Prompt structure is important!] --> B[Plan actions]; A --> C[Format outputs]; A --> D[Validate actions];
```

Helping LLMs reason and plan with Chain-of-Thought Prompting

LLMs can struggle with complex reasoning problems

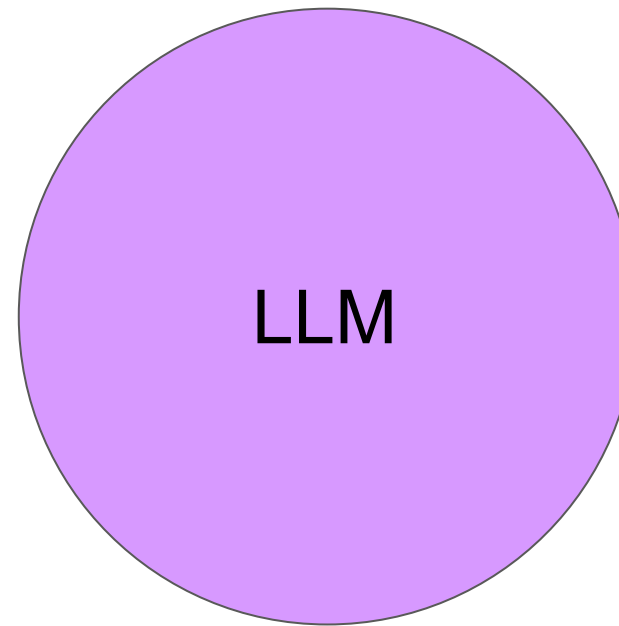
Prompt

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: The answer is 11

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

Model



Completion

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: The answer is 11

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

A: The answer is 27. ❌

Humans take a step-by-step approach to solving complex problems

Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

Start: Roger started with 5 balls.

Step 1: 2 cans of 3 tennis balls each is 6 tennis balls.

Step 2: $5 + 6 = 11$

End: The answer is 11

Reasoning steps

“Chain of thought”

Chain-of-Thought Prompting can help LLMs reason

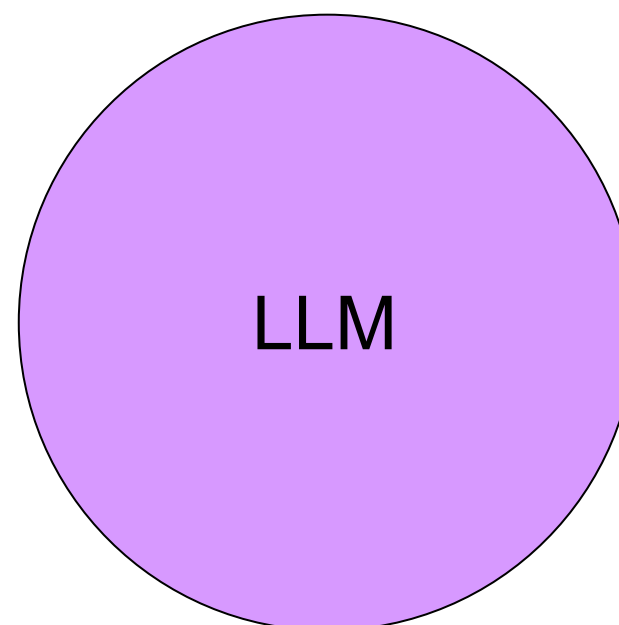
Prompt

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: Roger started with 5 balls. 2 cans of 3 tennis balls each is 6 tennis balls. $5 + 6 = 11$. The answer is 11.

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

Model



Completion

Q: Roger has 5 tennis balls.
...
...
...
how many apples do they have?

A: The cafeteria had 23 apples originally. They used 20 to make lunch. So they had $23 - 20 = 3$. They bought 6 more apples, so they have $3 + 6 = 9$. The answer is 9. ✓

Source: Wei et al. 2022, "Chain-of-Thought Prompting Elicits Reasoning in Large Language Models"

Chain-of-Thought Prompting can help LLMs reason

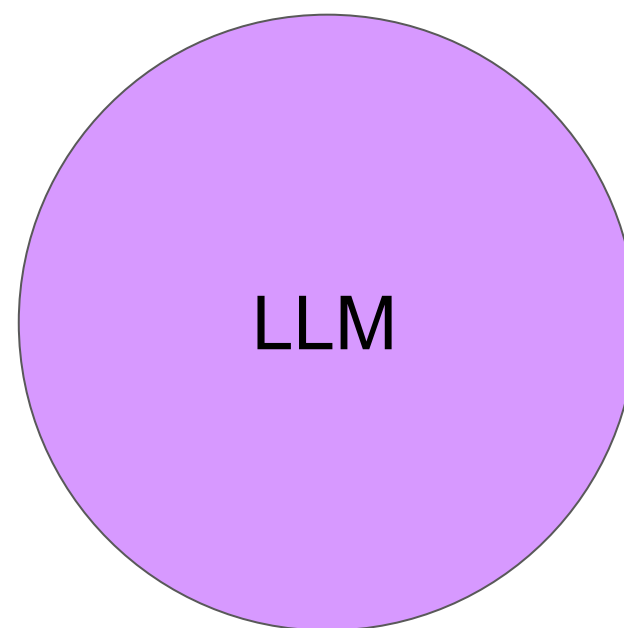
Prompt

Q: Yes or no: Would a pear sink in water?

A: The density of a pear is about 0.6 g/cm^3 , which is less than water. Thus, a pear would float. So the answer is no.

Q. Yes or no: Would a gold ring sink to the bottom of a swimming pool?

Model



Completion

Q: Yes or no: Would a pear sink in water?

...

...

So the answer is no.

The density of gold is 19.3 g/cm^3 , which is much greater than the density of water. Therefore, a gold ring would sink to the bottom of a swimming pool. So the answer is yes.

Source: Wei et al. 2022, "Chain-of-Thought Prompting Elicits Reasoning in Large Language Models"

Program-aided Language Models

LLMs can struggle with mathematics

Prompt

What is $40366 / 439$?

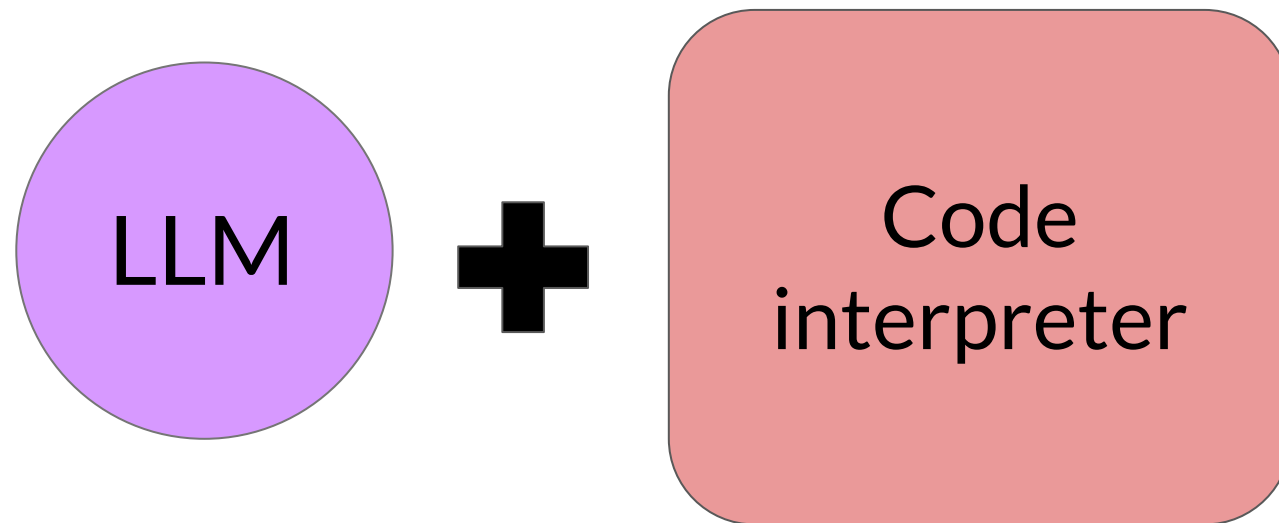
Model

LLM

Completion

What is $40366 / 439$?
92.549

Program-aided language (PAL) models



Chain-of-Thought (Wei et al., 2022)

Input

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: Roger started with 5 tennis balls. 2 cans of 3 tennis balls each is 6 tennis balls. $5 + 6 = 11$. The answer is 11.

Q: The bakers at the Beverly Hills Bakery baked 200 loaves of bread on Monday morning. They sold 93 loaves in the morning and 39 loaves in the afternoon. A grocery store returned 6 unsold loaves. How many loaves of bread did they have left?

Model Output

A: The bakers started with 200 loaves. They sold 93 in the morning and 39 in the afternoon. So they sold $93 + 39 = 132$ loaves. The grocery store returned 6 loaves. So they had $200 - 132 - 6 = 62$ loaves left.

The answer is 62.



Program-aided Language models (this work)

Input

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: Roger started with 5 tennis balls.

```
tennis_balls = 5
```

```
2 cans of 3 tennis balls each is
```

```
bought_balls = 2 * 3
```

```
tennis_balls
```

```
The answer is
```

```
answer = tennis_balls + bought_balls
```

Q: The bakers at the Beverly Hills Bakery baked 200 loaves of bread on Monday morning. They sold 93 loaves in the morning and 39 loaves in the afternoon. A grocery store returned 6 unsold loaves. How many loaves of bread did they have left?

Model Output

A: The bakers started with 200 loaves

```
loaves_baked = 200
```

```
They sold 93 in the morning and 39 in the afternoon
```

```
loaves_sold_morning = 93
```

```
loaves_sold_afternoon = 39
```

```
The grocery store returned 6 loaves.
```

```
loaves_returned = 6
```

```
The answer is
```

```
answer = loaves_baked - loaves_sold_morning  
- loaves_sold_afternoon + loaves_returned
```

```
>>> print(answer)
```

```
74
```



Source: Gao et al. 2022, "PAL: Program-aided Language Models"

PAL example

Prompt with one-shot example

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

Answer:

```
# Roger started with 5 tennis balls  
tennis_balls = 5  
# 2 cans of tennis balls each is  
bought_balls = 2 * 3  
# tennis balls. The answer is  
answer = tennis_balls + bought_balls
```

Q: The bakers at the Beverly Hills Bakery baked 200 loaves of bread on Monday morning. They sold 93 loaves in the morning and 39 loaves in the afternoon. A grocery store returned 6 unsold loaves. How many loaves did they have left?

PAL example

Prompt with one-shot example

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

Answer:

```
# Roger started with 5 tennis balls
tennis_balls = 5
# 2 cans of tennis balls each is
bought_balls = 2 * 3
# tennis balls. The answer is
answer = tennis_balls + bought_balls
```

Q: The bakers at the Beverly Hills Bakery baked 200 loaves of bread on Monday morning. They sold 93 loaves in the morning and 39 loaves in the afternoon. A grocery store returned 6 unsold loaves. How many loaves did they have left?

Completion, CoT reasoning (blue), and PAL execution (pink)

Answer:

```
# The bakers started with 200 loaves
```

```
loaves_baked = 200 ←
```

```
# They sold 93 in the morning and 39 in the
afternoon
```

```
loaves_sold_morning = 93 ←
```

```
loaves_sold_afternoon = 39 ←
```

```
# The grocery store returned 6 loaves.
```

```
loaves_returned = 6 ←
```

```
# The answer is
```

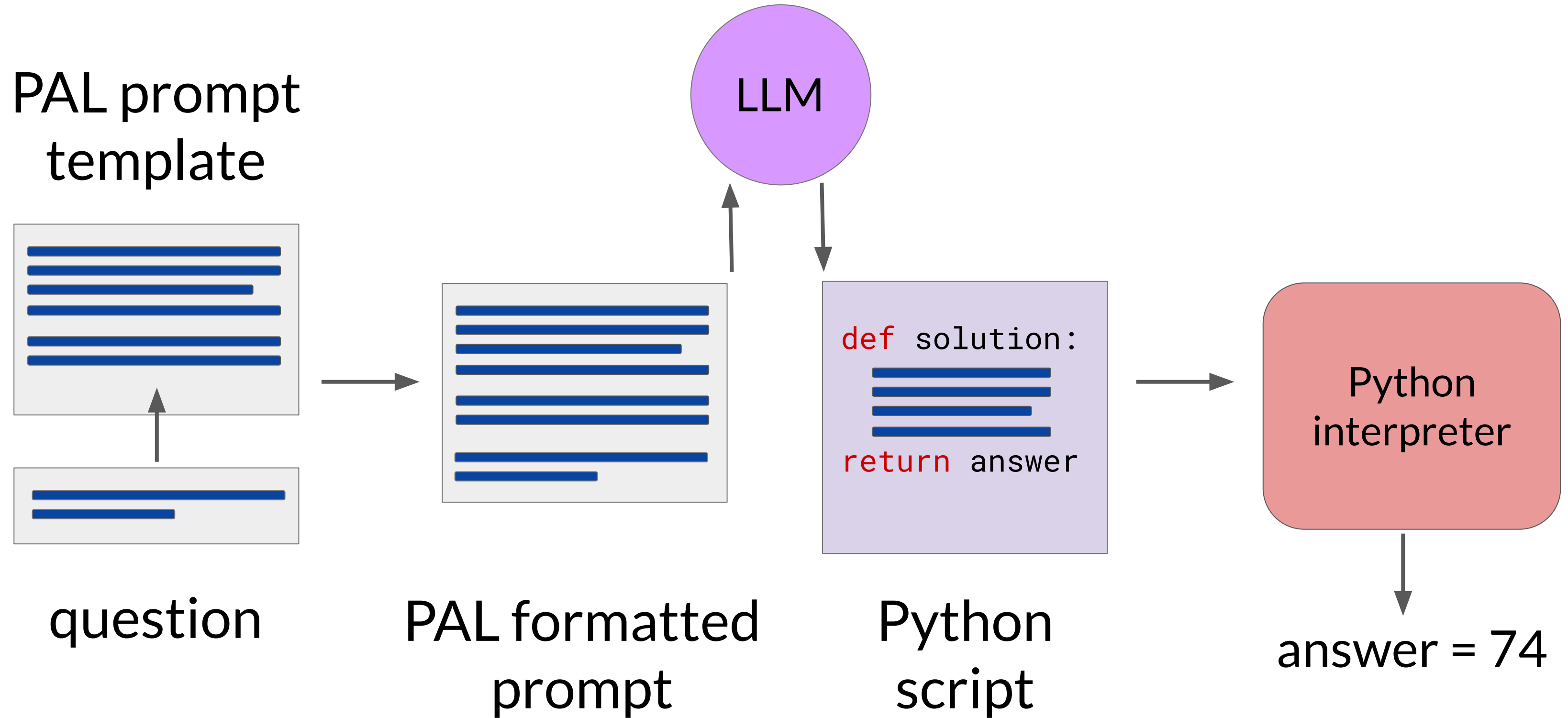
```
answer = loaves_baked
```

```
- loaves_sold_morning
```

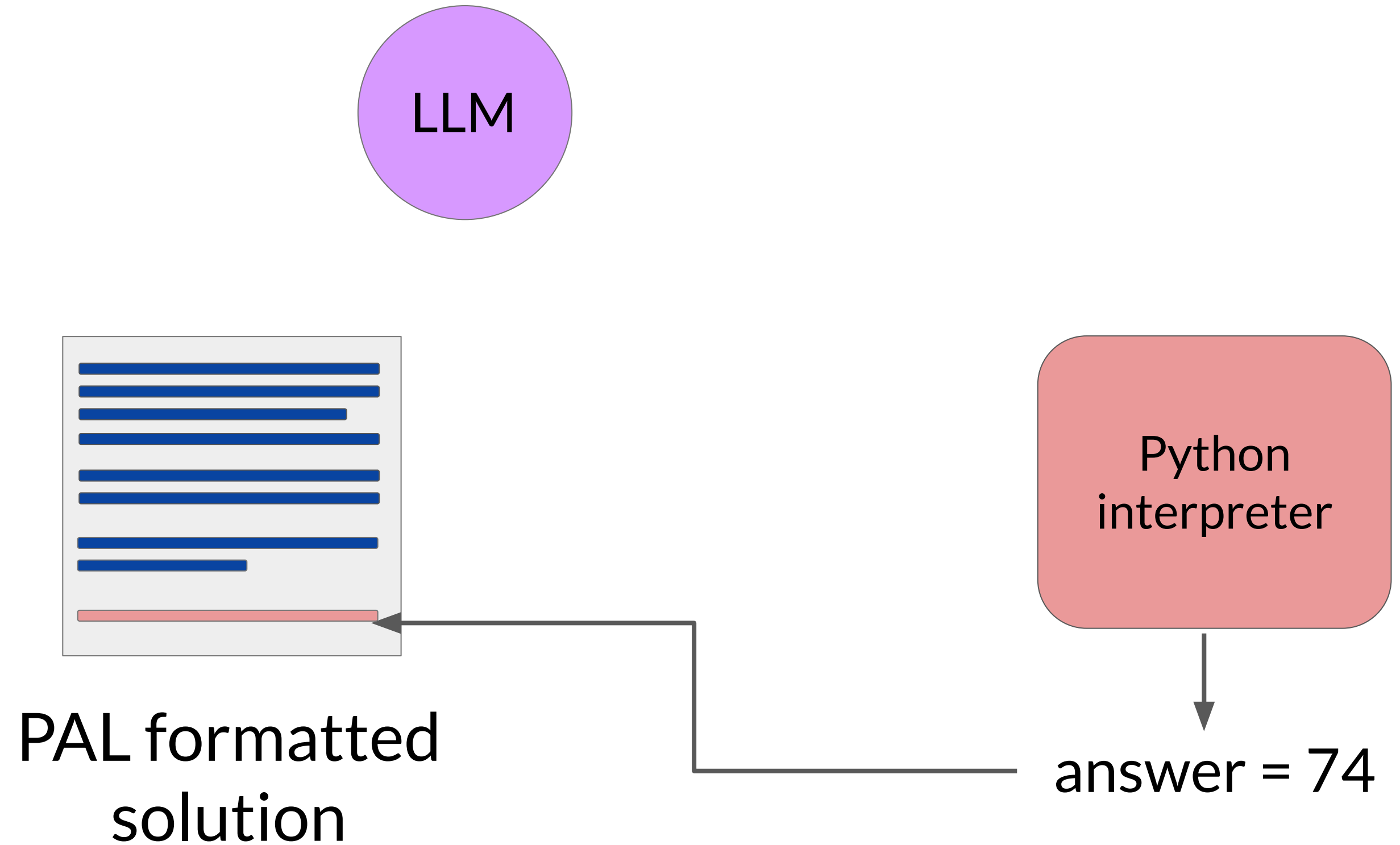
```
- loaves_sold_afternoon
```

```
+ loaves_returned
```

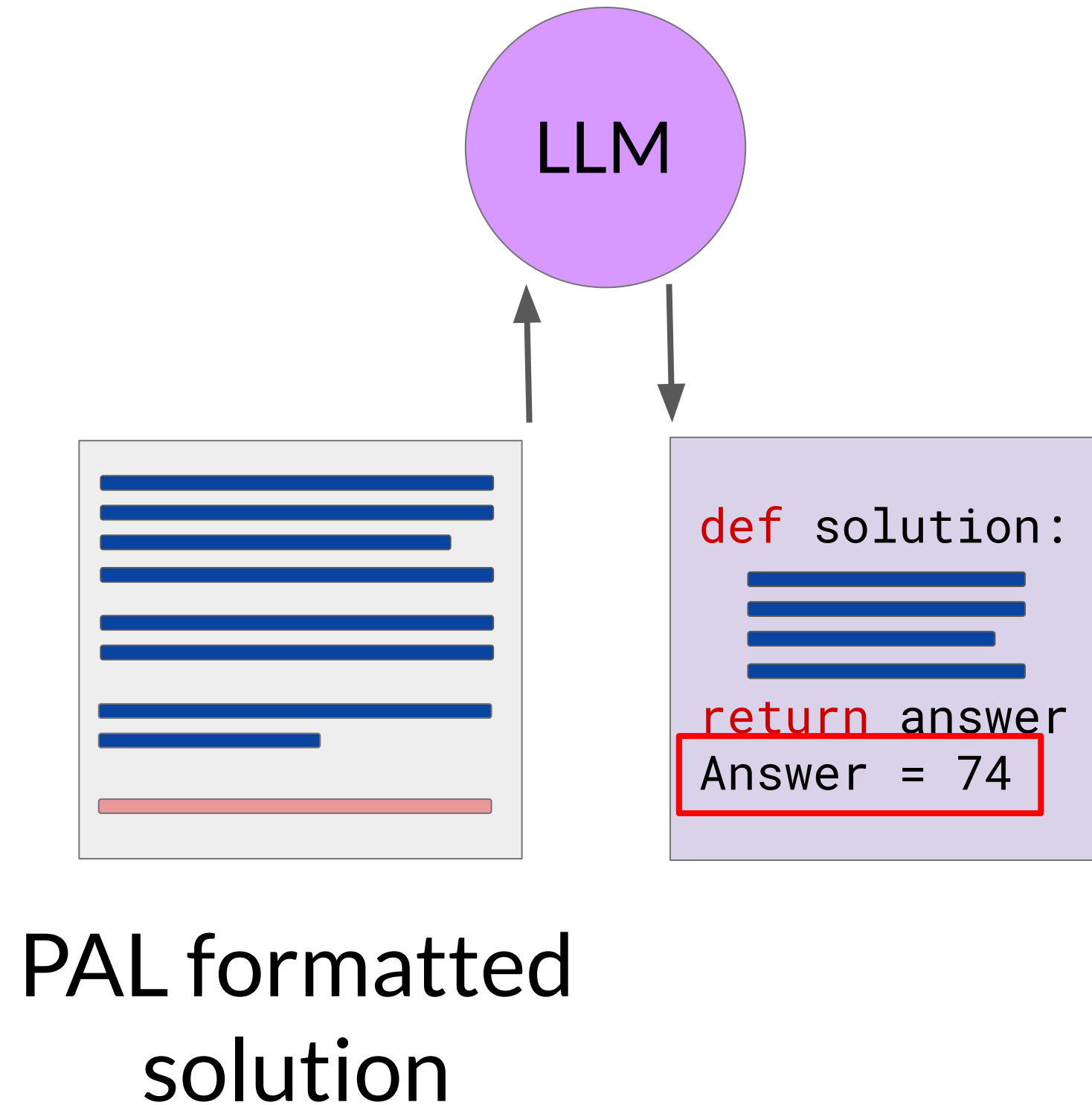
Program-aided language (PAL) models



Program-aided language (PAL) models

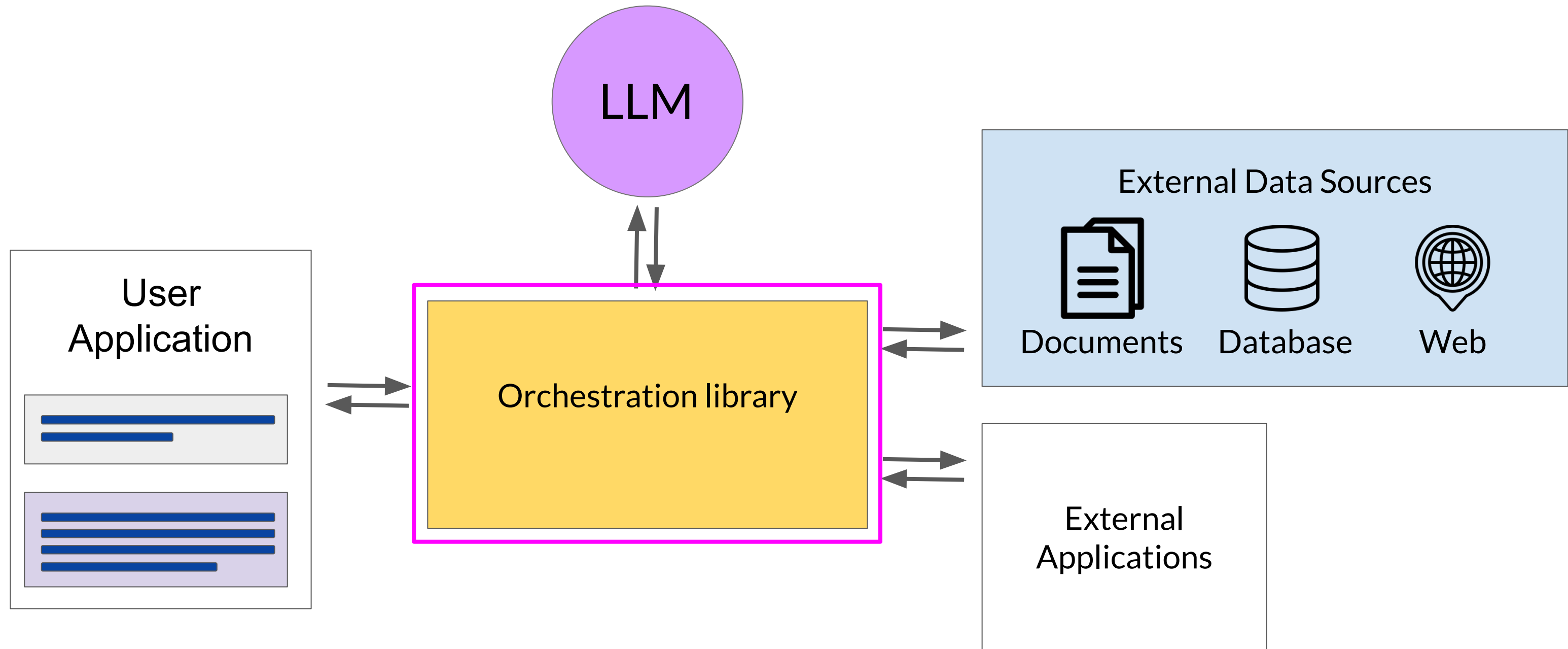


Program-aided language (PAL) models

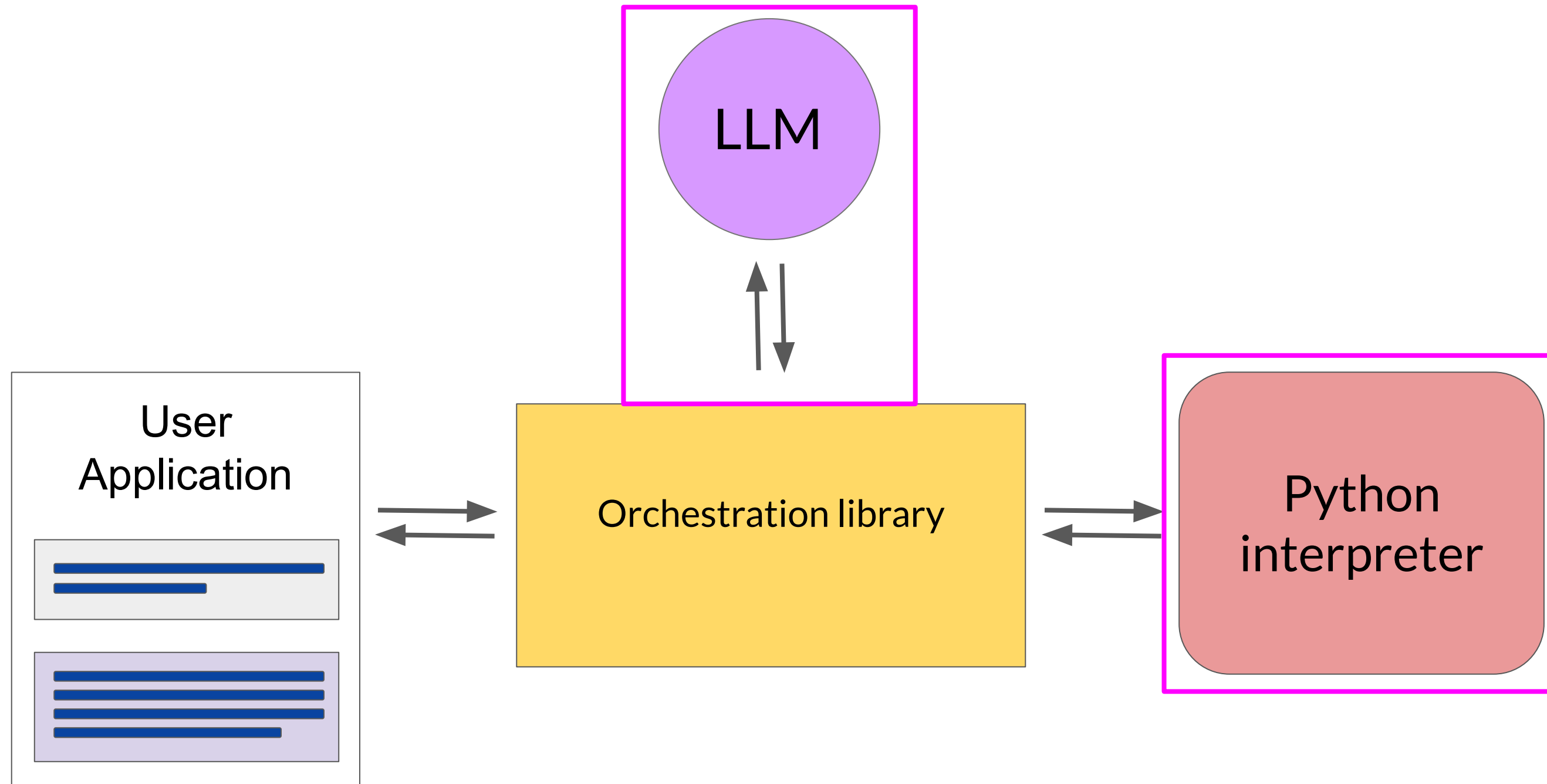


Completion with
correct answer

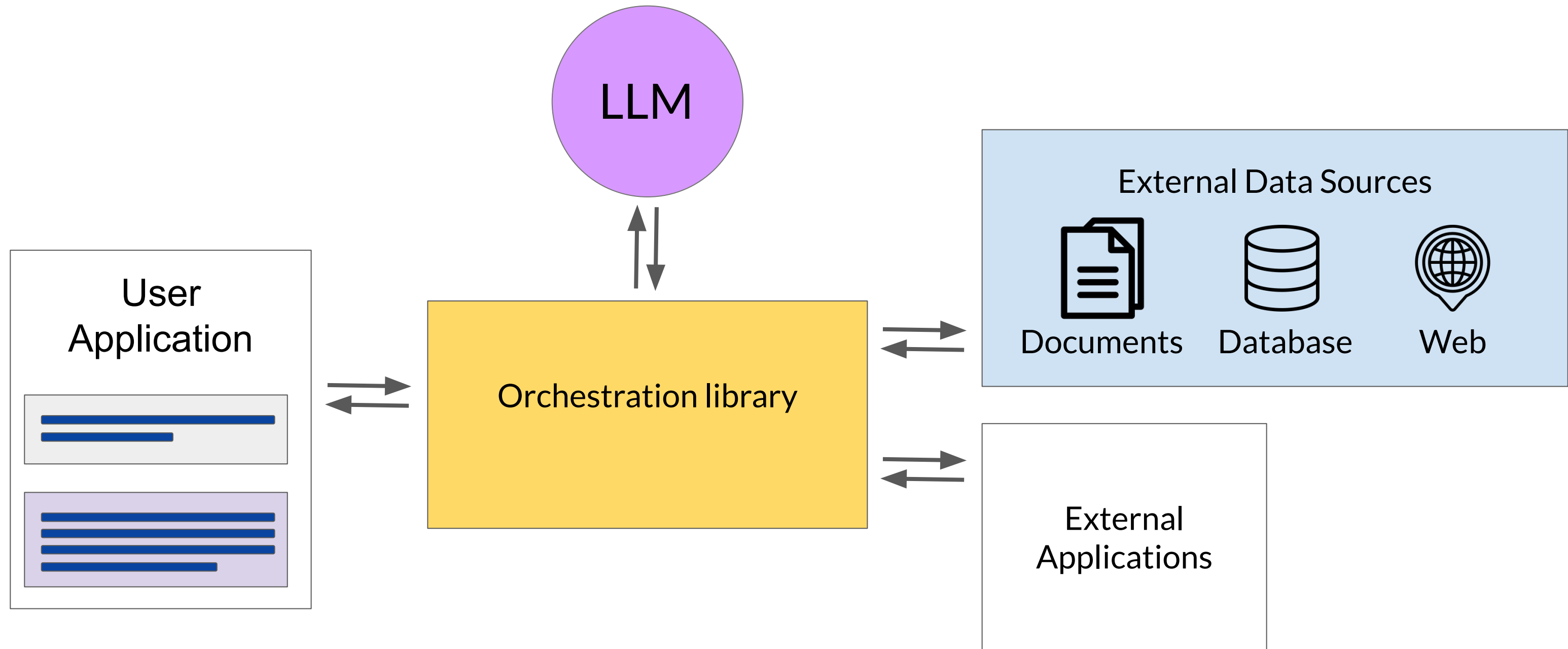
LLM-powered applications



PAL architecture

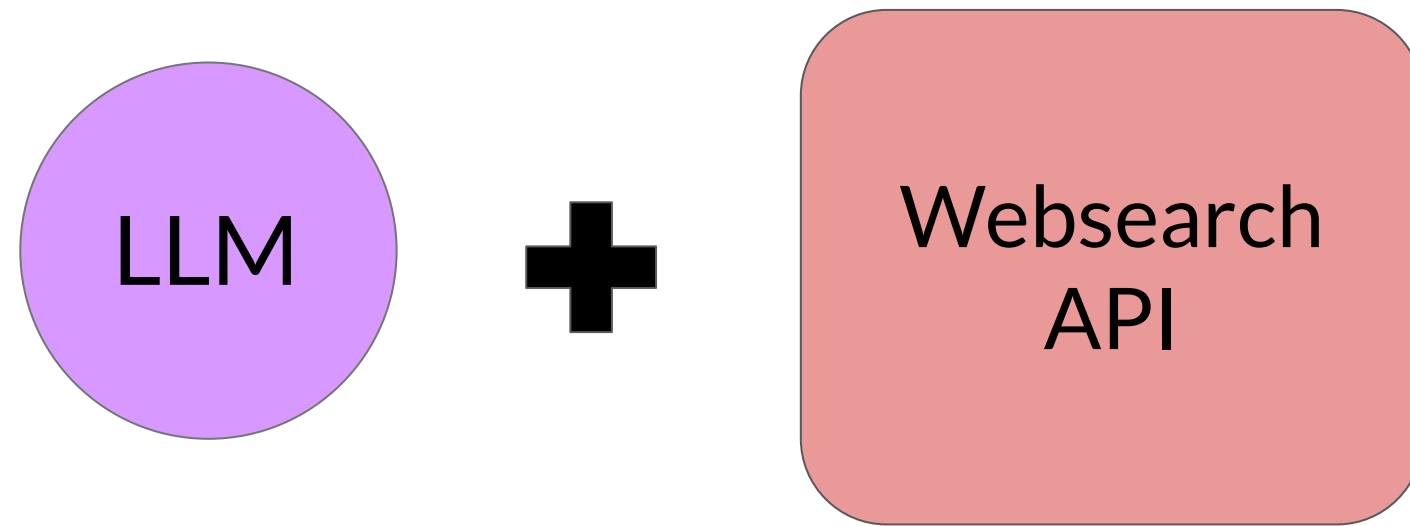


LLM-powered applications



ReAct: Combining reasoning and action in LLMs

ReAct: Synergizing Reasoning and Action in LLMs

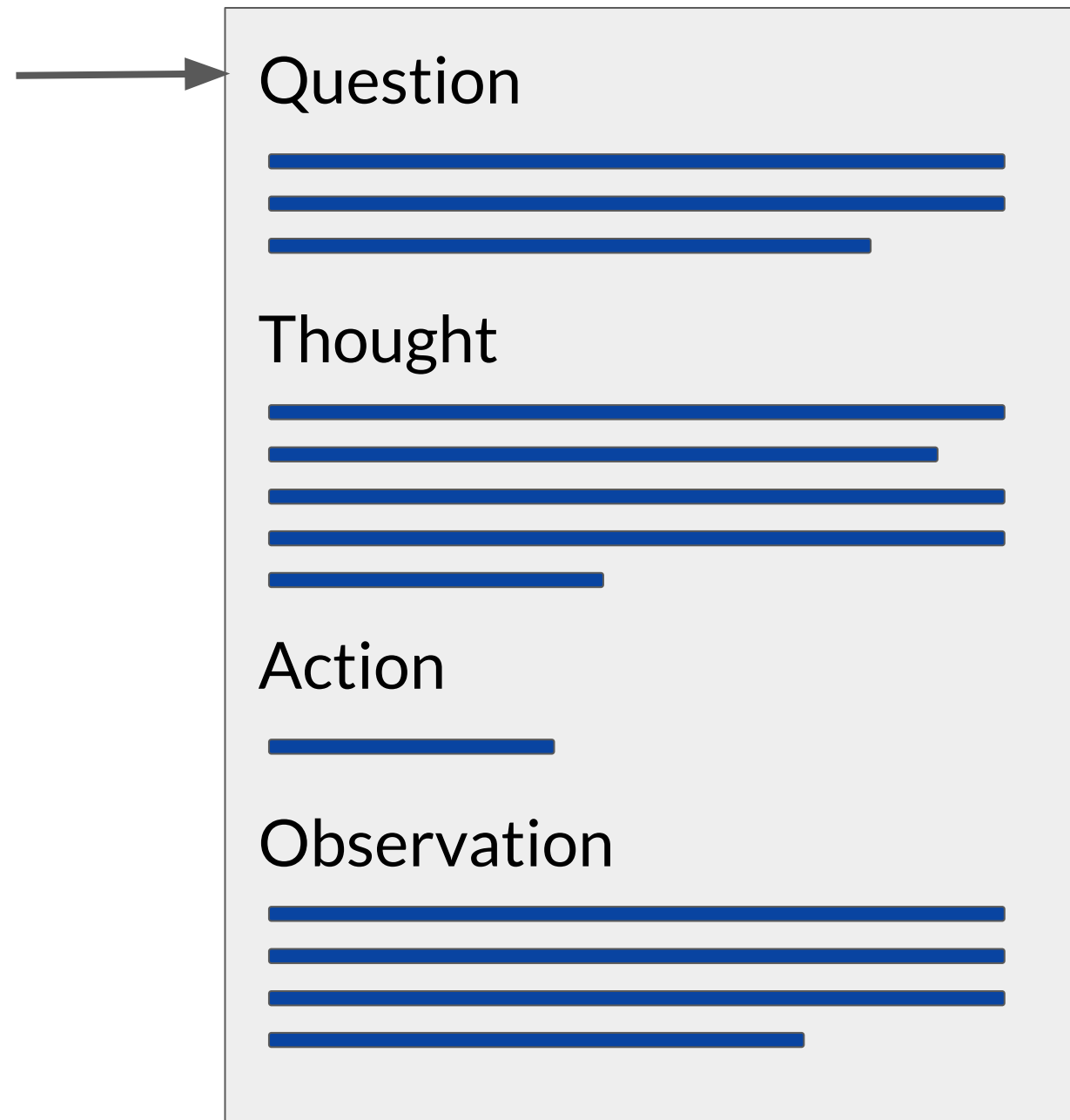


HotPot QA: multi-step question answering
Fever: Fact verification

<p>(1) Hotspot QA</p> <p>Question: Aside from the Apple Remote, what other device can control the program Apple Remote was originally designed to interact with?</p>	<p>(1d) ReAct (Reason + Act)</p> <p>Thought 1: I need to search Apple Remote and find the program it was originally designed to interact with. Act 1: Search[Apple Remote] Obs 1: The Apple Remote is a remote control introduced in October 2005 by Apple ... originally designed to control the Front Row media center program ...</p>	
<p>(1a) Standard</p> <p>Answer: iPod ❌</p>	<p>(1c) Act-Only</p> <p>Act 1: Search[Apple Remote] Obs 1: The Apple Remote is a remote control ...</p>	
<p>(1b) CoT (Reason Only)</p> <p>Thought: Let's think step by step. Apple Remote was originally designed to interact with Apple TV. Apple TV can be controlled by iPhone, iPad, and iPod Touch. So the answer is iPhone, iPad, and iPod Touch. Answer: iPhone, iPad, iPod Touch ❌</p>	<p>Act 2: Search[Front Row] Obs 2: Could not find [Front Row]. Similar: ... Act 3: Search[Front Row (software)] Obs 3: Front Row is a discontinued media center software ... Act 4: Finish[yes] ❌</p>	
<p>Thought 2: Apple Remote was originally designed to control the Front Row media center program. I need to search Front Row next and find what other device can control it. Act 2: Search[Front Row] Obs 2: Could not find [Front Row]. Similar: ['Front Row Seat to Earth', 'Front Row Motorsports', 'Front Row (software)', ...] Thought 3: Front Row is not found. I need to search Front Row (software) ... Act 3: Search[Front Row (software)] Obs 3: Front Row is a discontinued media center software ... Thought 4: Front Row (software) is controlled by an Apple Remote or the keyboard function keys. So the answer is keyboard function keys. Act 4: Finish[keyboard function keys] ✅</p>		
<p>(2) AlfWorld</p> <p>You are in the middle of a room. Looking quickly around you, you see a cabinet 6, a cabinet 1, a coffee machine 1, a countertop 3, a stove burner 1, and a toaster 1. Your task is to: Put some pepper shaker on a drawer.</p>		<p>(2b) ReAct (Reason + Act)</p> <p>Act 1: Think[First I need to find a pepper shaker...more likely to appear in cabinets (1-6), countertops (1-3), ...] Act 2: Go to cabinet 1 Obs 2: On the cabinet 1, you see a vase 2. (Here the agent go to cabinet 1, then cabinet 2, 3, then countertop 1 and 2) Act 6: Go to countertop 3 Obs 6: On the countertop 3, you see a apple 1, a bread 1, a pepper shaker 1, and a vase 3. Act 7: Take pepper shaker 1 from countertop 3 Obs 7: You pick up the pepper shaker 1 from the countertop 3. Act 8: Think[Now I find a pepper shaker 1. Next, I need to put it in/on drawer 1.] Act 9: Go to drawer 1 Obs 9: Drawer 1 is closed. Act 10: Open drawer 1 Obs 10: You open Drawer 1 ... Act 11: Put pepper shaker 1 in/on drawer 1 Obs 11: You put pepper shaker 1 in/on the drawer 1. ✅</p>
<p>(2a) Act-Only</p> <p>Act 1: Go to drawer 1 Obs 1: The drawer 1 is closed. Act 2: Open drawer 1 Obs 2: You open the drawer 1. The drawer 1 is open. In it, you see a dish sponge 2, and a spoon 1. Act 3: Go to sinkbasin 1 Obs 3: On the sinkbasin 1, you see a dish sponge 3, a spatula 1, and a spoon 2. Act 4: Take peppershaker 1 from sinkbasin 1 Obs 4: Nothing happens. Act 5: Take peppershaker 1 from sinkbasin 1 Obs 5: Nothing happens. ❌</p>		

Source: Yao et al. 2022, "ReAct: Synergizing Reasoning and Acting in Language Models"

ReAct: Synergizing Reasoning and Action in LLMs



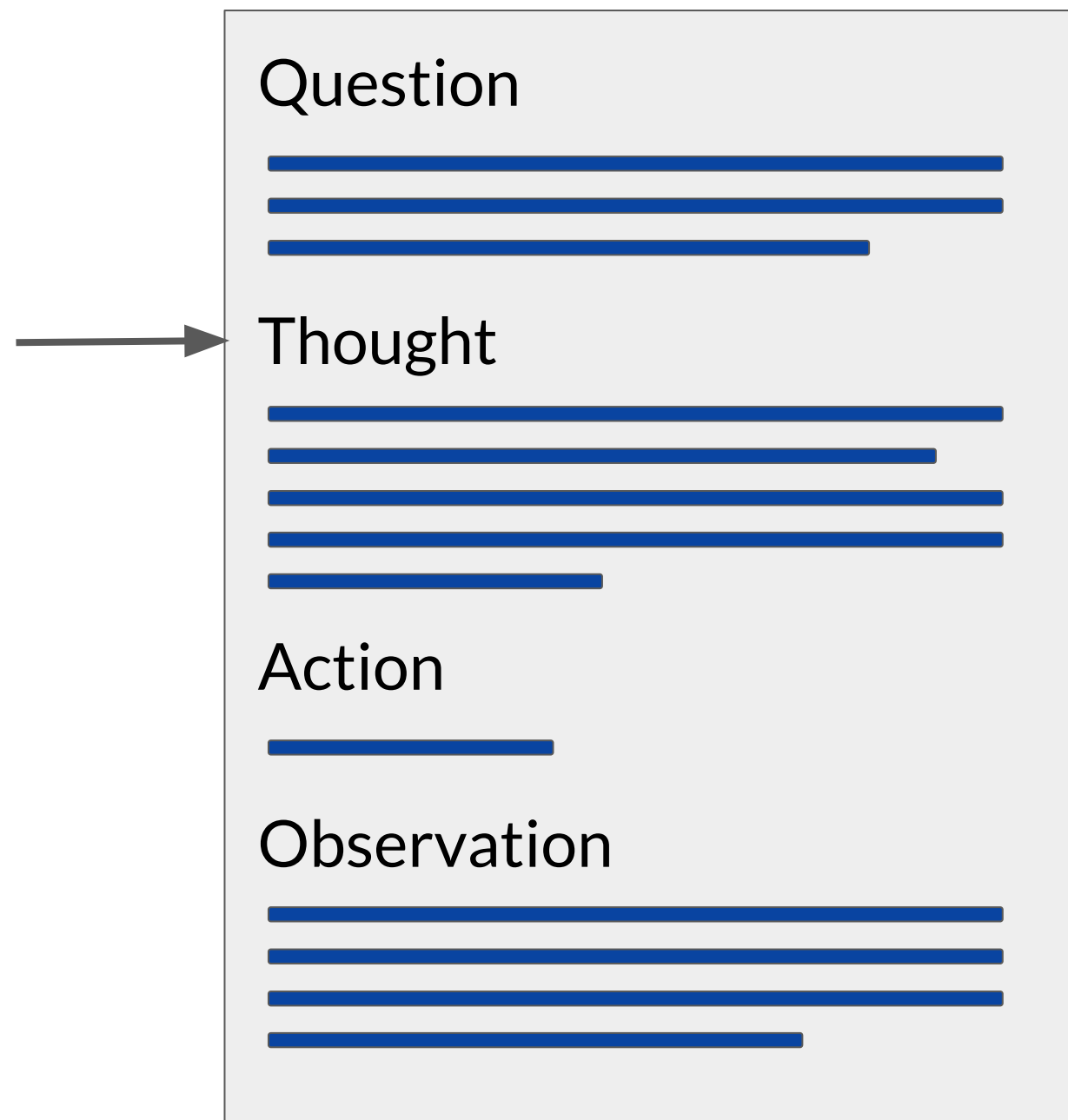
Question: Problem that requires advanced reasoning and multiple steps to solve.

E.g.

“Which magazine was started first, *Arthur’s Magazine* or *First for Women*?”

Source: Yao et al. 2022, “ReAct: Synergizing Reasoning and Acting in Language Models”

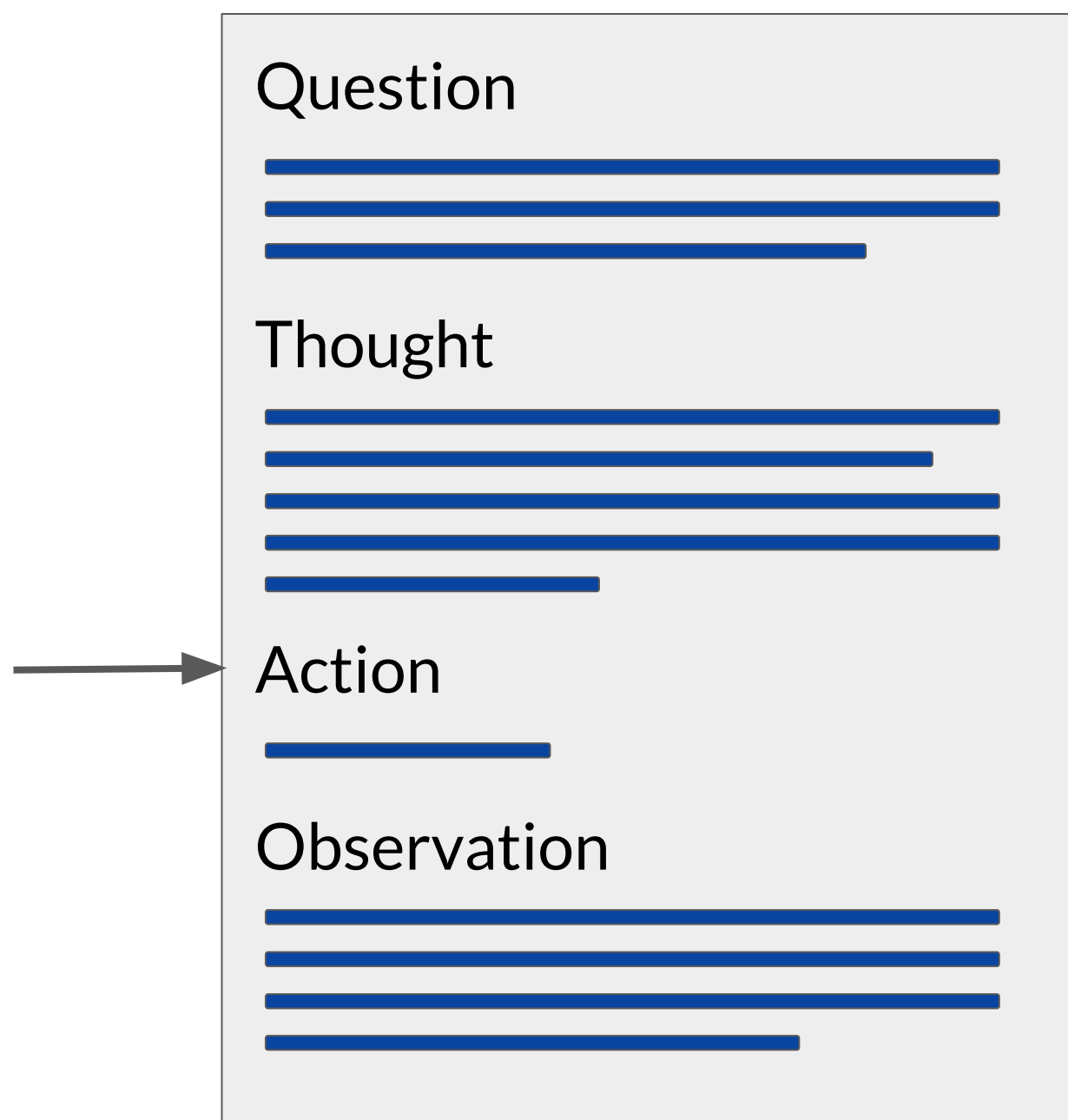
ReAct: Synergizing Reasoning and Action in LLMs



Thought: A reasoning step that identifies how the model will tackle the problem and identify an action to take.

“I need to search Arthur’s Magazine and First for Women, and find which one was started first.”

ReAct: Synergizing Reasoning and Action in LLMs



Action: An external task that the model can carry out from an allowed set of actions.

E.g.

search[entity]

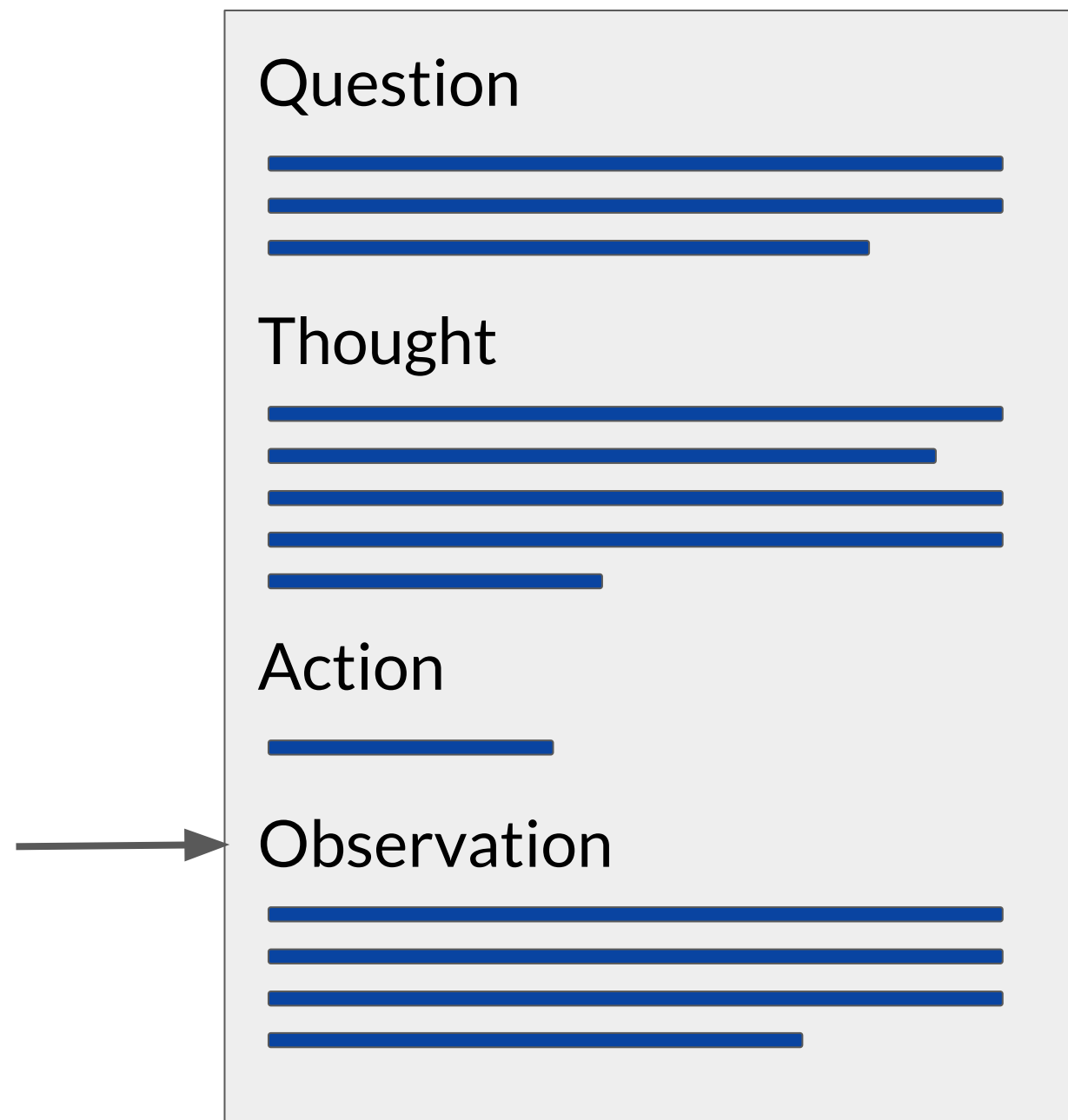
lookup[string]

finish[answer]

Which one to choose is determined by the information in the preceding thought.

search[Arthur's Magazine]

ReAct: Synergizing Reasoning and Action in LLMs

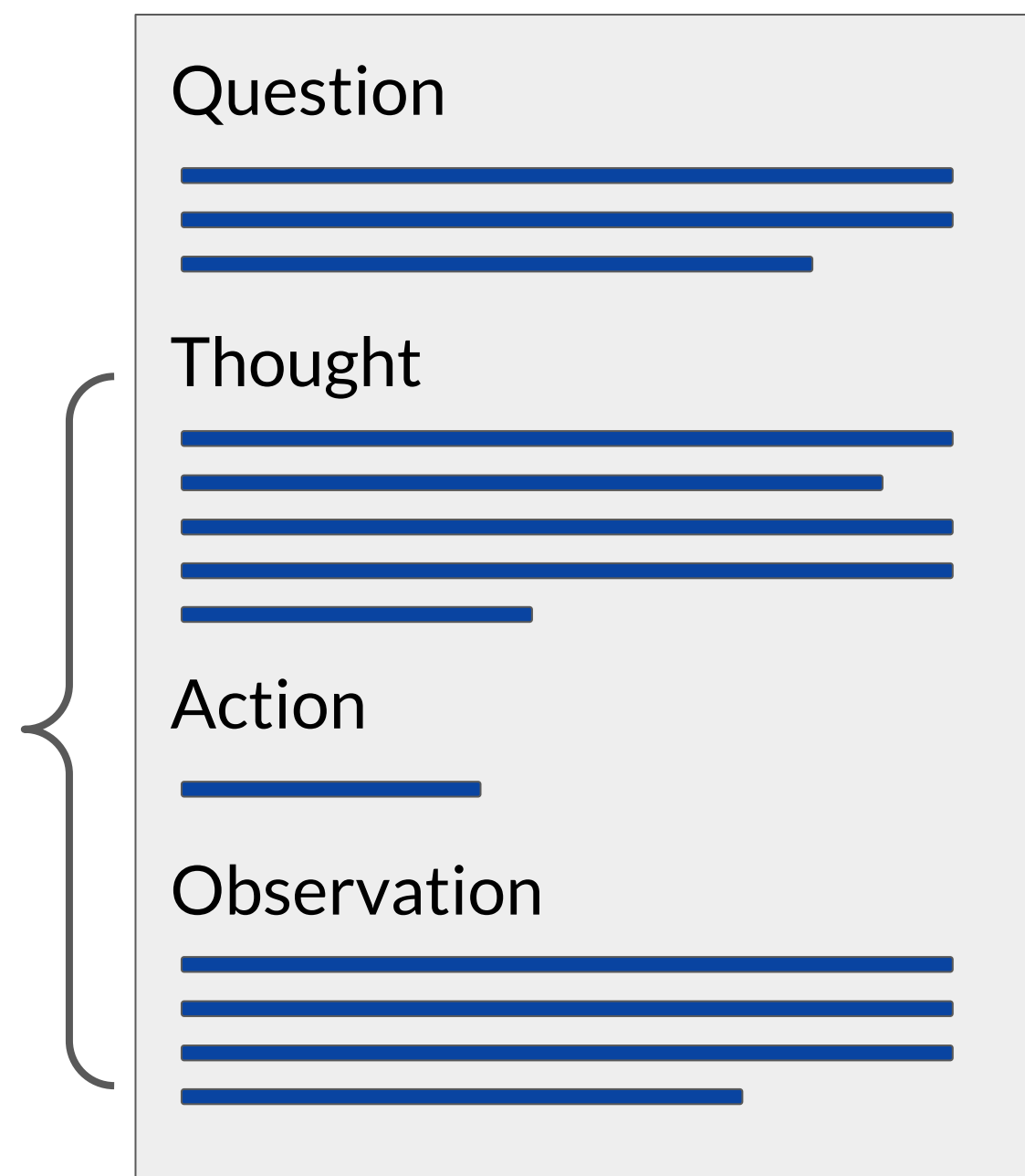


Observation: the result of carrying out the action

E.g.

“Arthur’s Magazine (1844-1846) was an American literary periodical published in Philadelphia in the 19th century.”

ReAct: Synergizing Reasoning and Action in LLMs



Thought 2:

“Arthur’s magazine was started in 1844. I need to search First for Women next.”

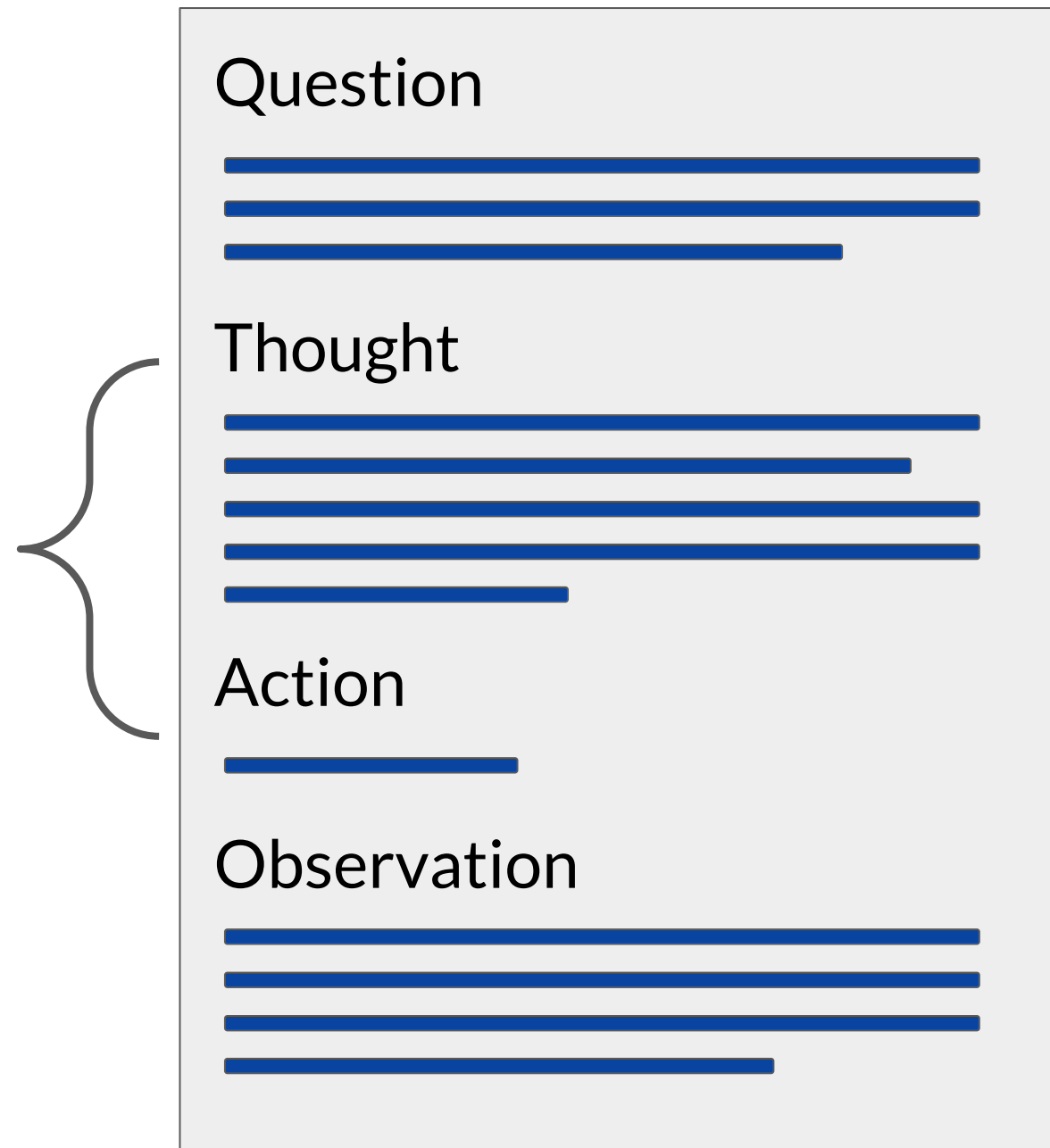
Action 2:

`search[First for Women]`

Observation 2:

“First for Women is a woman’s magazine published by Bauer Media Group in the USA.[1] The magazine was started in 1989.”

ReAct: Synergizing Reasoning and Action in LLMs



Thought 3:

“First for Women was started in 1989.
1844 (Arthur’s Magazine) < 1989 (First for
Women), so Arthur’s Magazine as started
first”

Action 2:

finish[Arthur’s Magazine]

ReAct instructions define the action space

Solve a question answering task with interleaving Thought, Action, Observation steps.

Thought can reason about the current situation, and Action can be three types:

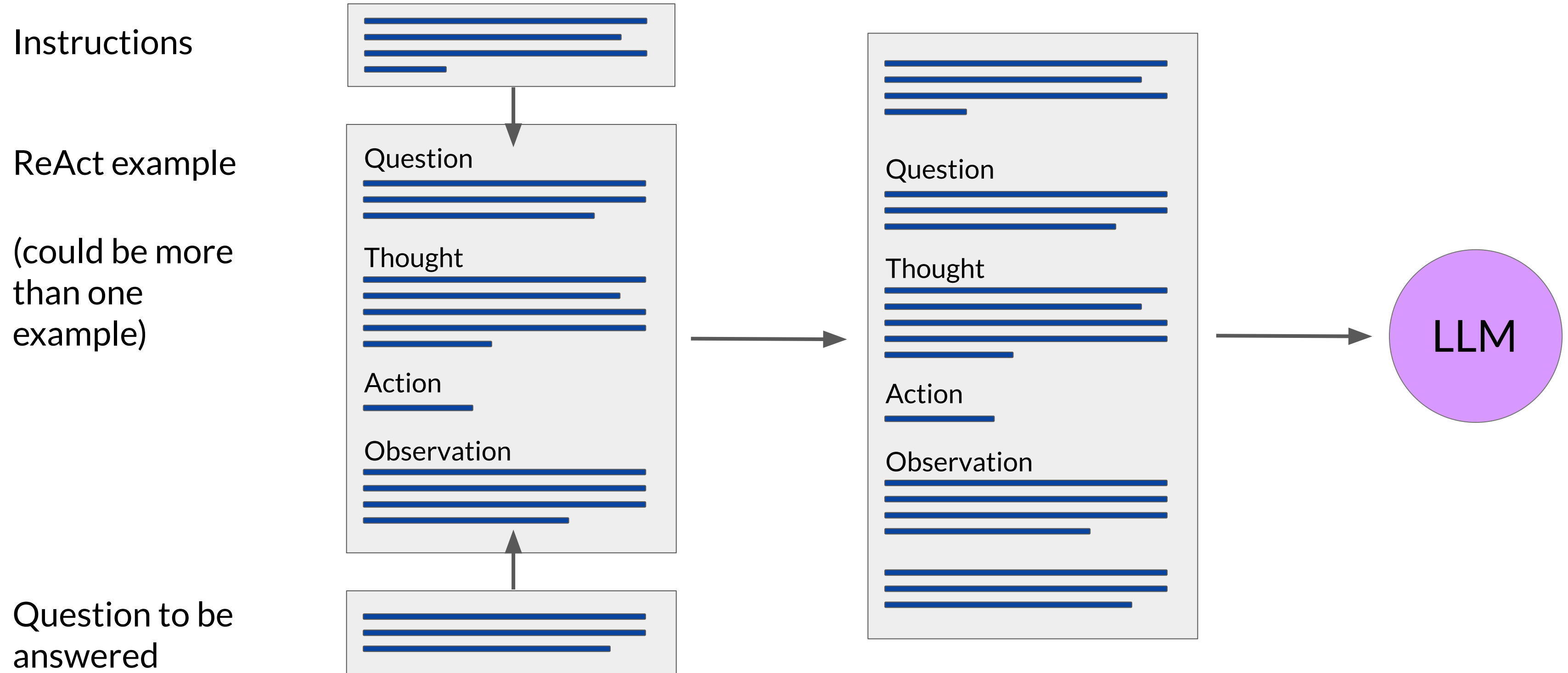
(1) `Search[entity]`, which searches the exact entity on Wikipedia and returns the first paragraph if it exists. If not, it will return some similar entities to search.

(2) `Lookup[keyword]`, which returns the next sentence containing keyword in the current passage.

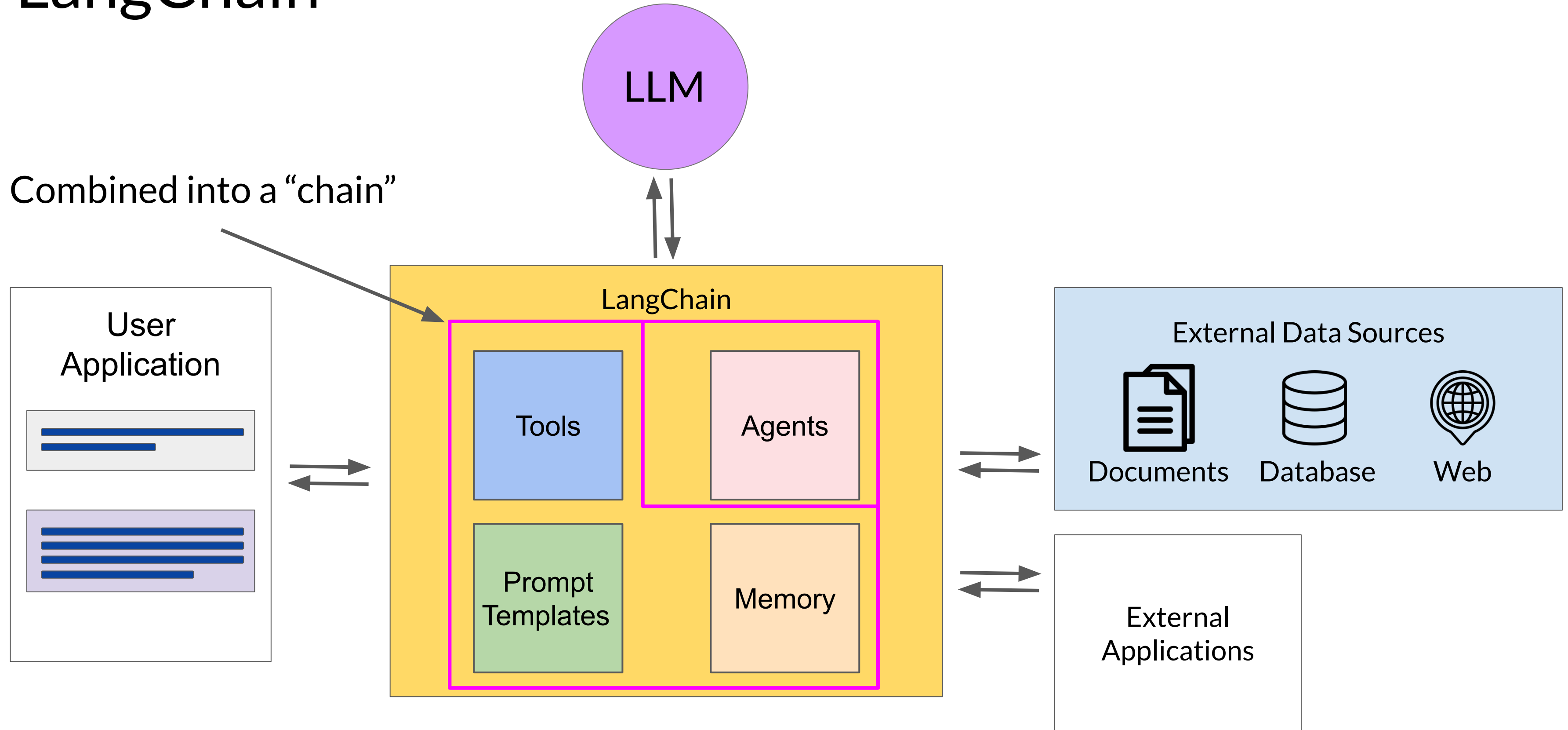
(3) `Finish[answer]`, which returns the answer and finishes the task.

Here are some examples.

Building up the ReAct prompt



LangChain



The significance of scale: application building

BERT*
110M

BLOOM
176B



*Bert-base

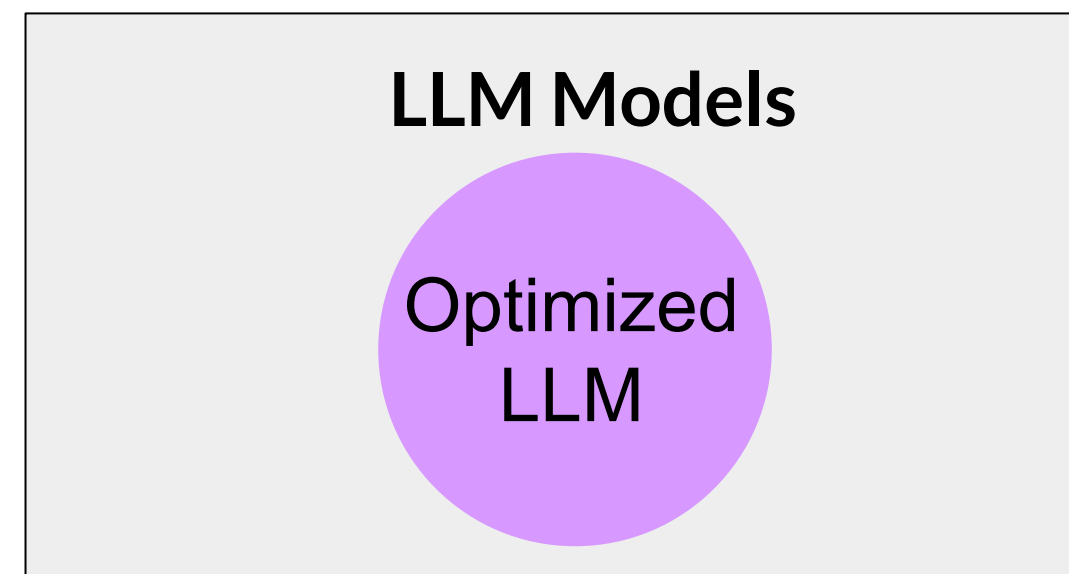
LLM powered application architectures

Building generative applications



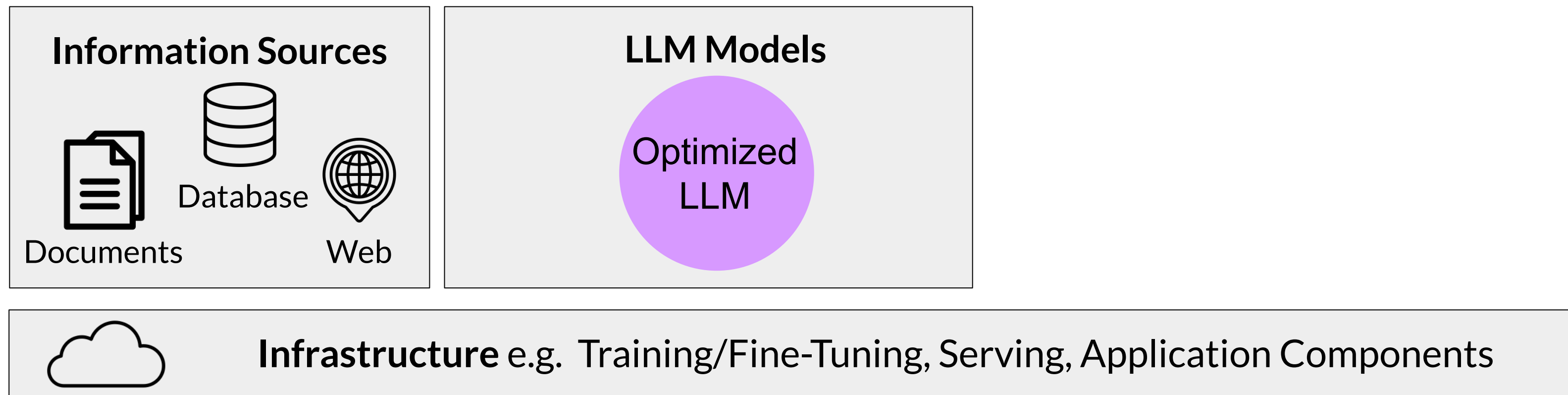
Infrastructure e.g. Training/Fine-Tuning, Serving, Application Components

Building generative applications

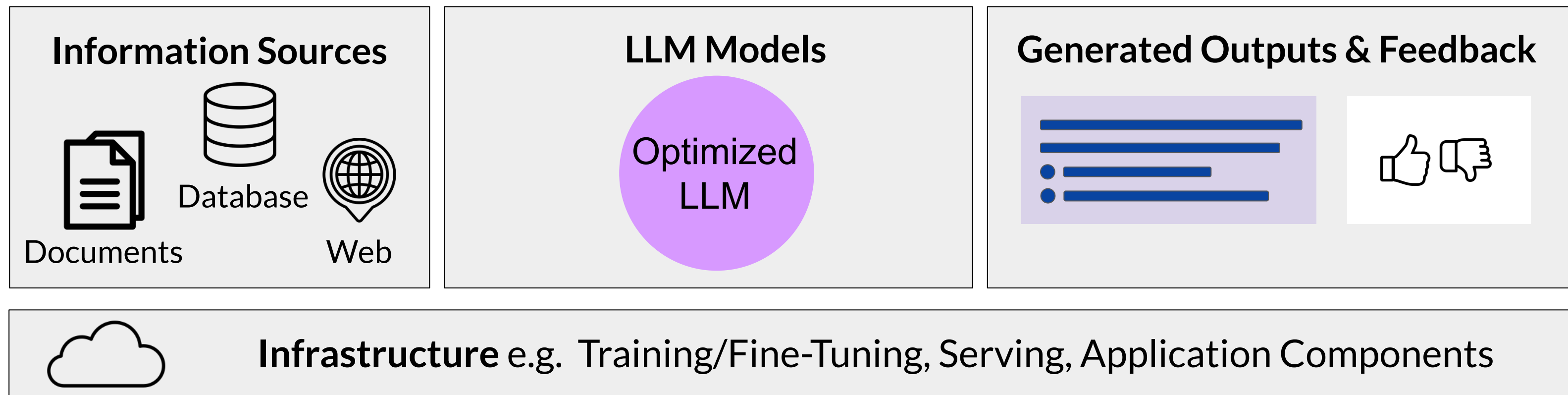


Infrastructure e.g. Training/Fine-Tuning, Serving, Application Components

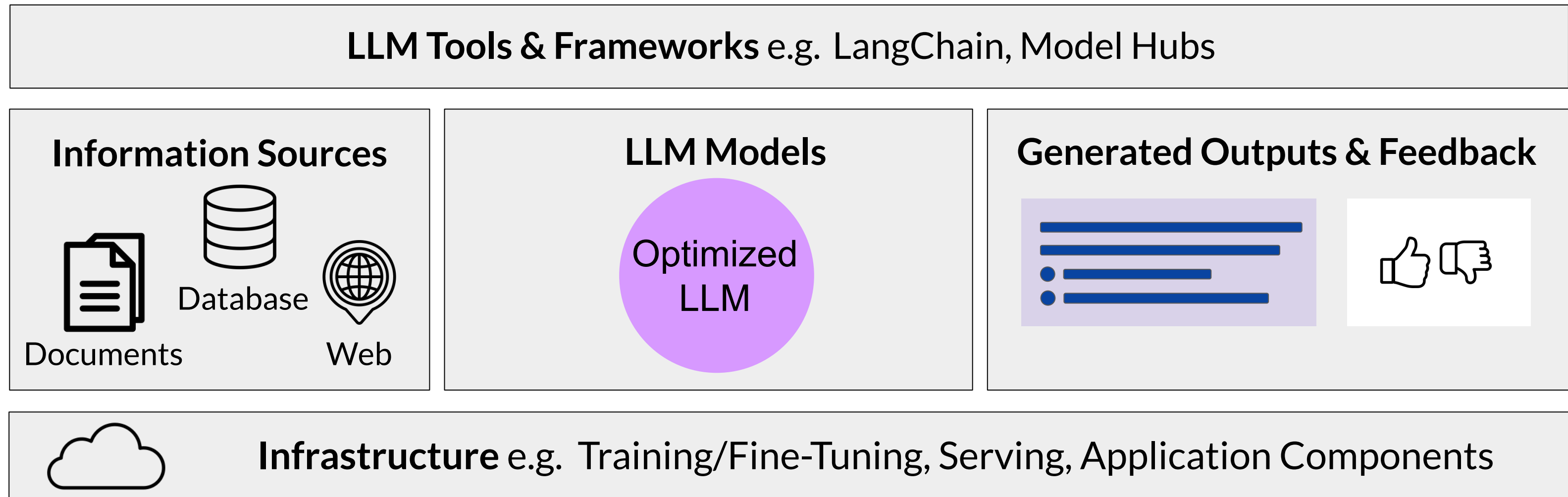
Building generative applications



Building generative applications



Building generative applications



Building generative applications

Application Interfaces e.g. Websites, Mobile Applications, APIs, etc.

LLM Tools & Frameworks e.g. LangChain, Model Hubs

Information Sources



Documents



Database

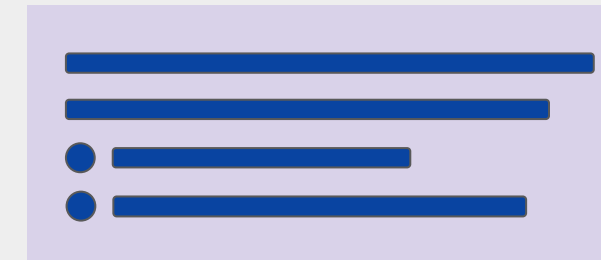


Web

LLM Models

Optimized
LLM

Generated Outputs & Feedback



Infrastructure e.g. Training/Fine-Tuning, Serving, Application Components

Building generative applications

Consumers



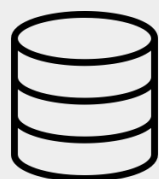
Application Interfaces e.g. Websites, Mobile Applications, APIs, etc.

LLM Tools & Frameworks e.g. LangChain, Model Hubs

Information Sources



Documents



Database

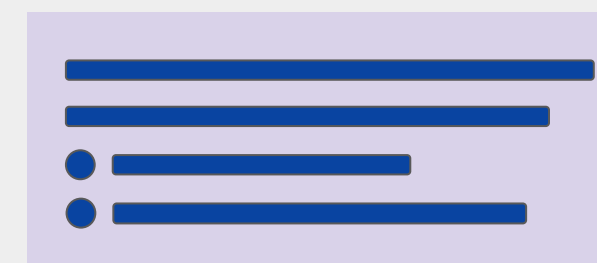


Web

LLM Models

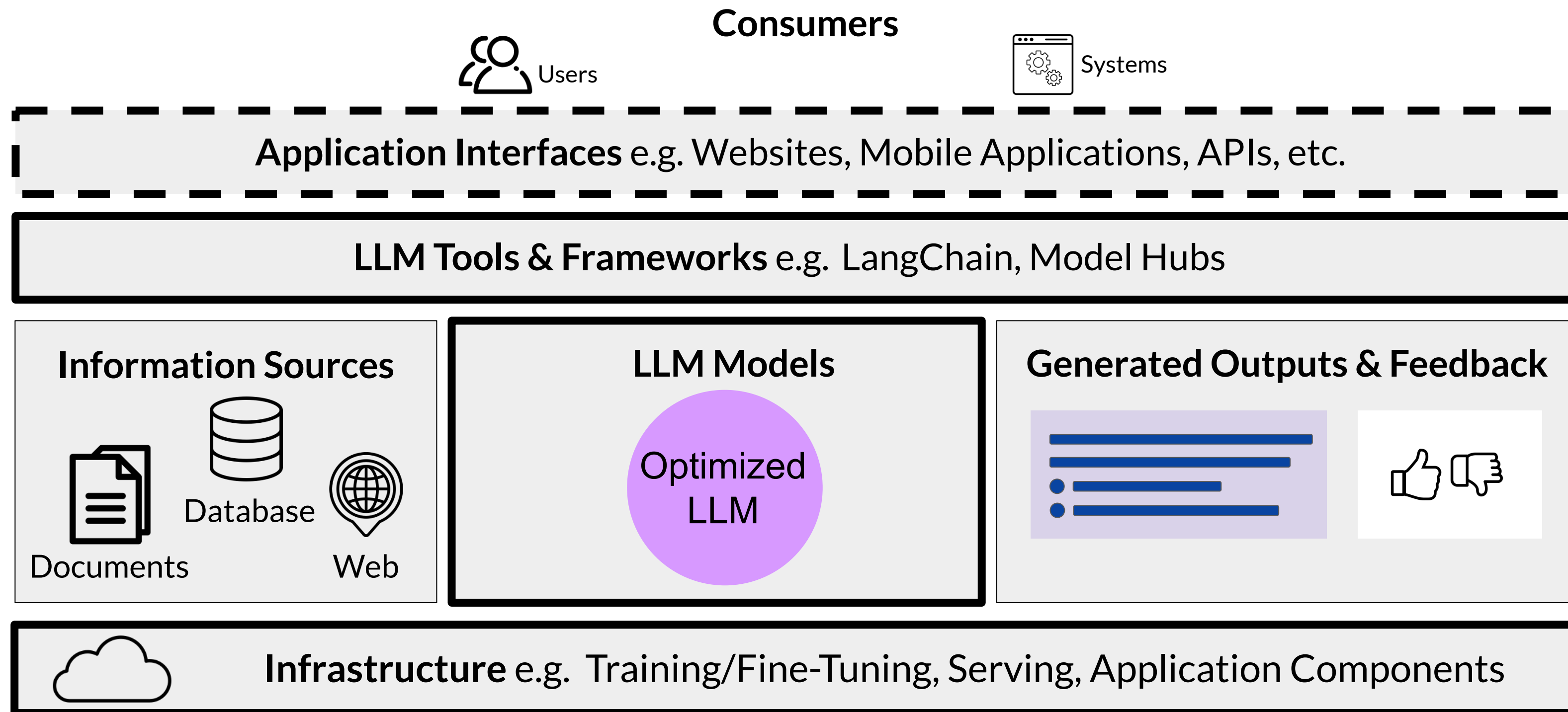
Optimized
LLM

Generated Outputs & Feedback



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Building generative applications



Conclusion, Responsible AI, and on-going research





Responsible AI

Dr. Nashlie Sephus

Responsible AI

Dr. Nashlie

Sephus



Responsible AI

Dr. Nashlie Sephus

On-going research

- Responsible AI

Responsible AI

Special challenges of responsible generative AI

- Toxicity
- Hallucinations
- Intellectual Property

Toxicity

LLM returns responses that can be potentially harmful or discriminatory towards protected groups or protected attributes

How to mitigate?

- Careful curation of training data
- Train guardrail models to filter out unwanted content
- Diverse group of human annotators

Hallucinations

LLM generates factually incorrect content

How to mitigate?

- Educate users about how generative AI works
- Add disclaimers
- Augment LLMs with independent, verified citation databases
- Define intended/unintended use cases

Intellectual Property

Ensure people aren't plagiarizing, make sure there aren't any copyright issues

How to mitigate?

- Mix of technology, policy, and legal mechanisms
- Machine "unlearning"
- Filtering and blocking approaches

Responsibly build and use generative AI models

- Define use cases: the more specific/narrow, the better
- Assess risks for each use case
- Evaluate performance for each use case
- Iterate over entire AI lifecycle

On-going research

- Responsible AI
- Scale models and predict performance
- More efficiencies across model development lifecycle
- Increased and emergent LLM capabilities