Logic-RL: Unleashing LLM Reasoning with Rule-Based Reinforcement Learning

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Background

Improving the reasoning capabilities of language models to better assist in mathematical reasoning, code generation, and other real-world applications has become a prominent research focus. Although large language models have demonstrated remarkable performance in these tasks, the more successful cases are all large-scale models supported by substantial computational resources. Aligning smaller-scale models offers a promising approach to investigating language model alignment when computational resources are limited. This raises the question:

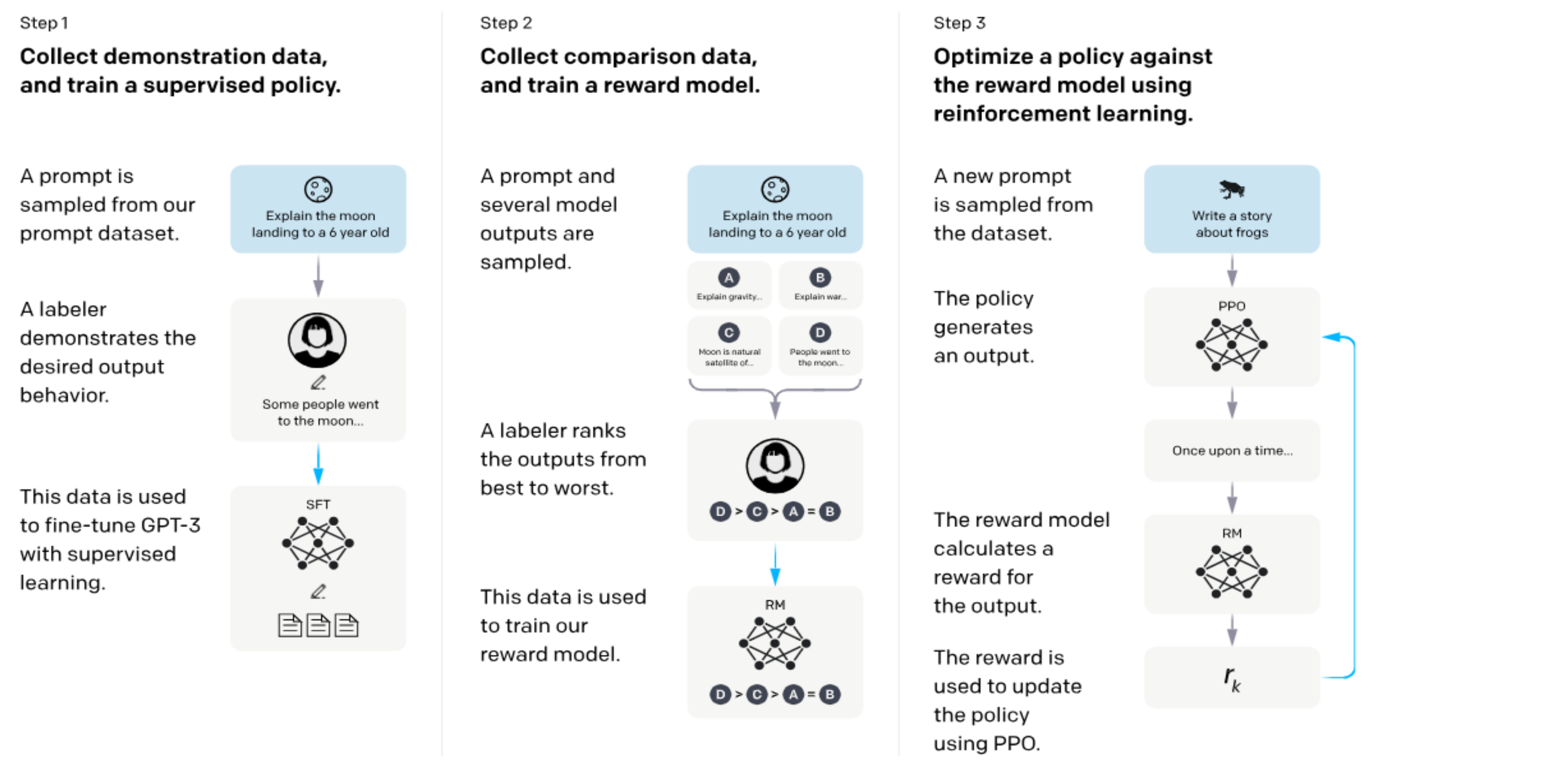
Can similar reasoning abilities emerge in smaller-scale models?

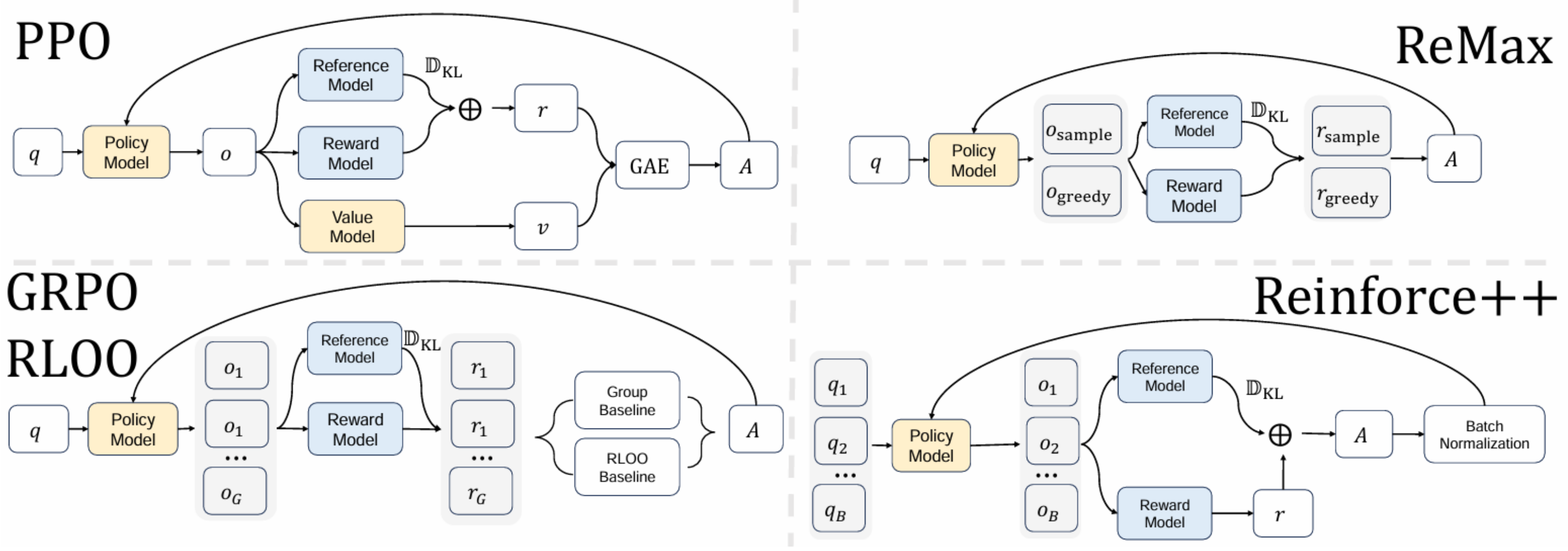
Synthetic Logic Puzzles Framework

An example of a Knights and Knaves (K&K) puzzle	
Problem	Knights always tell the truth, and knaves always lie. You meet 2 inhabitants: Zoey, and Oliver. Zoey: "*Oliver is not a knight*". Oliver: "*Oliver is a knight if and only if Zoey is a knave*". So who is a knight and who is a knave?
Solution	(1)Zoey is a knave; (2)Oliver is a knight.

Reward Type	Reward Value	Condition
s_{answer}	2	The answer fully matches the ground truth
	-1.5	The answer partially matches the ground truth
	-2	The answer cannot be parsed or missing
s_{format}	1	The format is correct
	-1	The format is incorrect

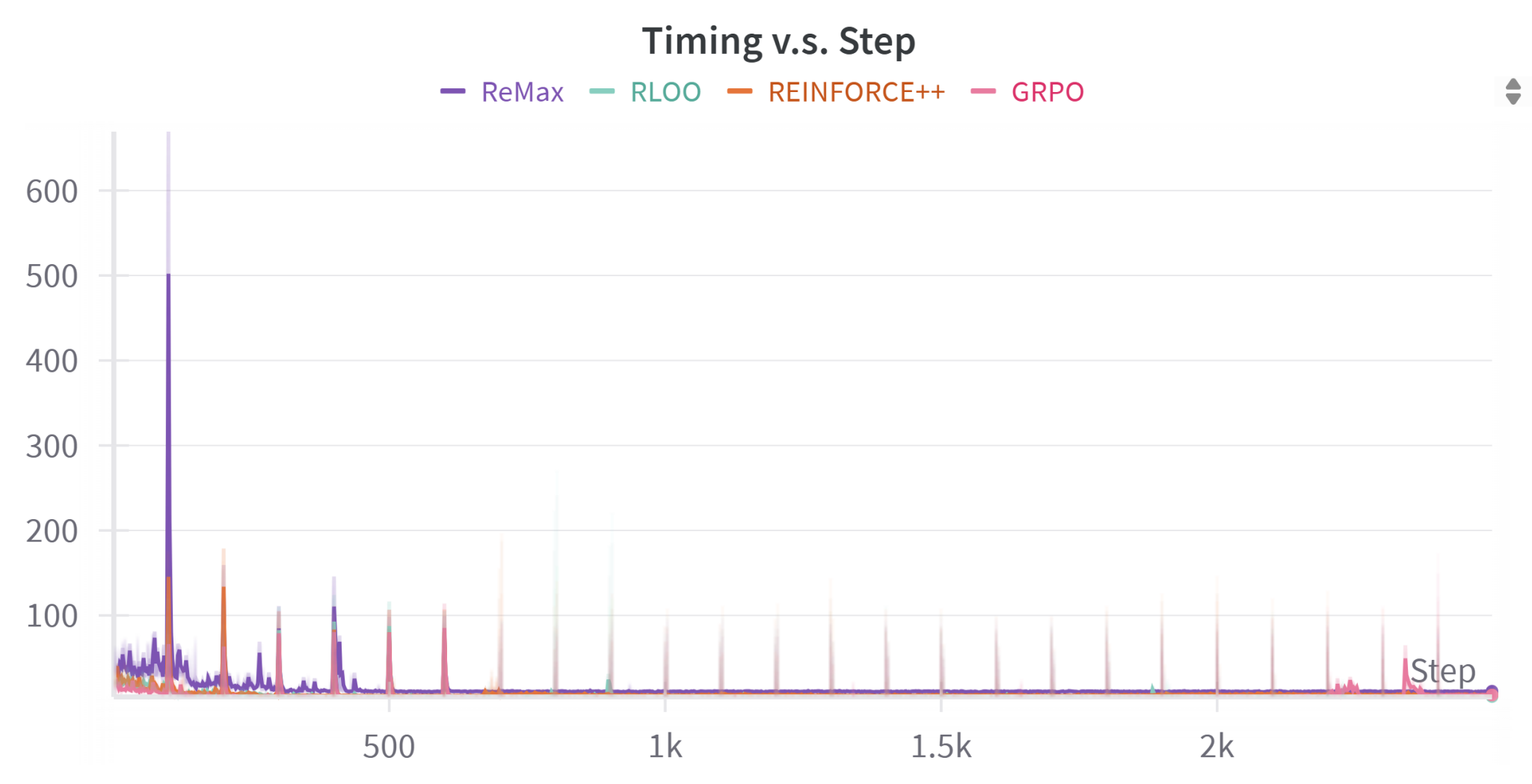
Post Training Method Overview

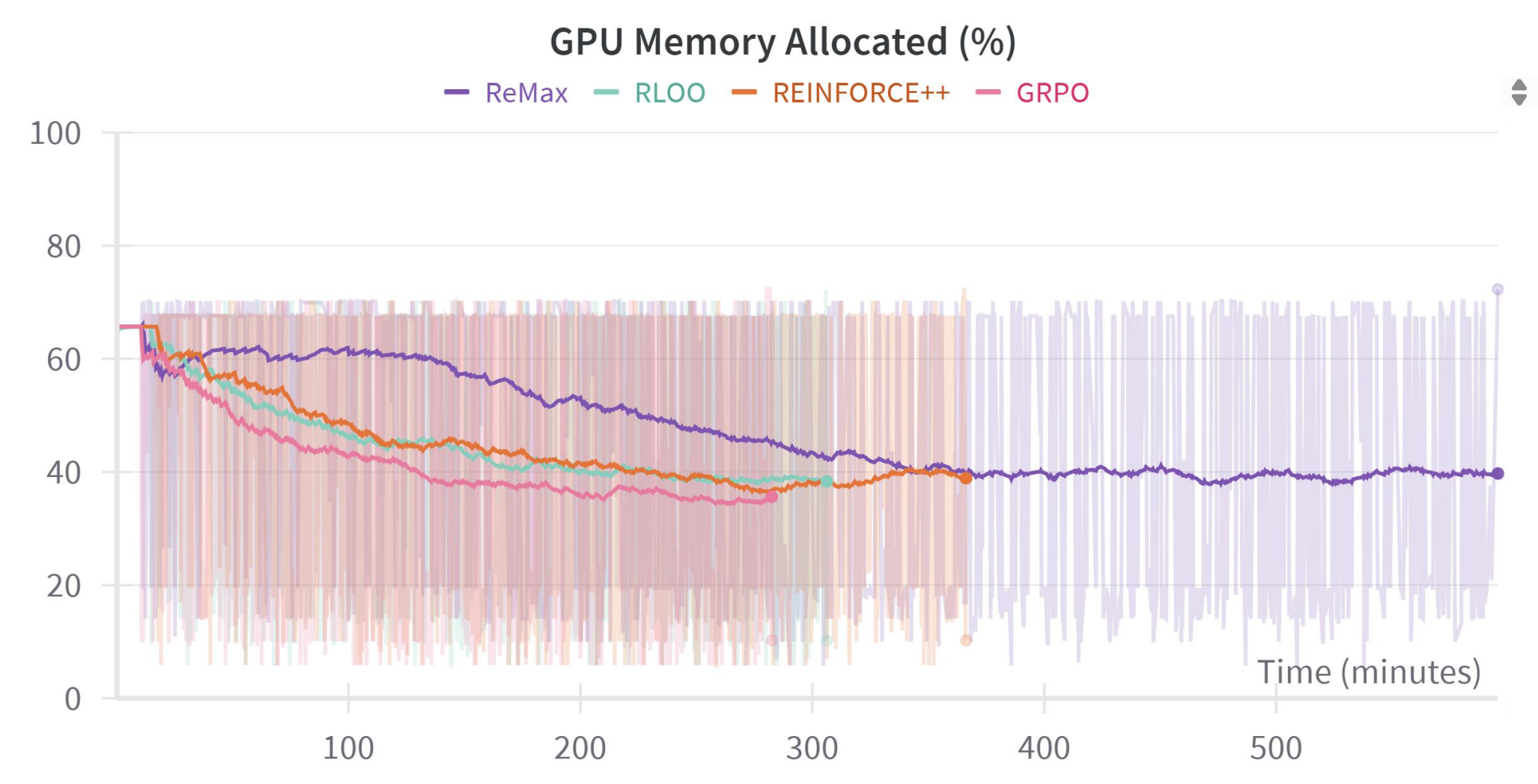

Step 1
Collect demonstration data, and train a supervised policy.
A prompt is sampled from our prompt dataset.
Explain the moon landing to a 6 year old
A labeler demonstrates the desired output behavior.
Some people went to the moon...
This data is used to fine-tune GPT-3 with supervised learning.
SFT
Step 2
Collect comparison data, and train a reward model.
A prompt and several model outputs are sampled.
Explain the moon landing to a 6 year old
A Explain gravity...
B Explain war...
C Moon is natural satellite of...
D People went to the moon...
A labeler ranks the outputs from best to worst.
D > C > A = B
This data is used to train our reward model.
RM
D > C > A = B
Step 3
Optimize a policy against the reward model using reinforcement learning.
A new prompt is sampled from the dataset.
Write a story about frogs
The policy generates an output.
PPO
Once upon a time...
The reward model calculates a reward for the output.
RM
The reward is used to update the policy using PPO.
r_k



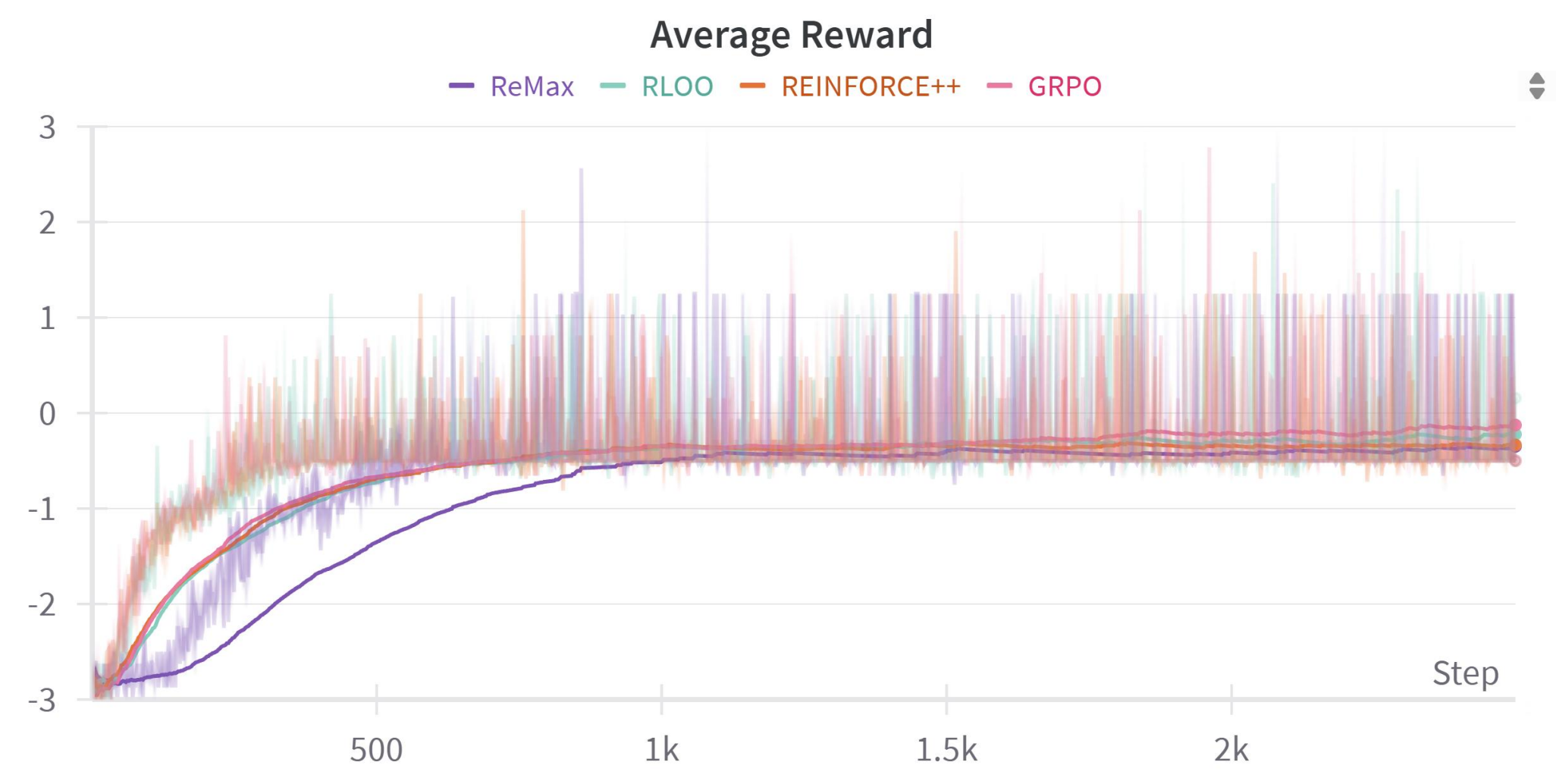
Experiments Results And Discussion

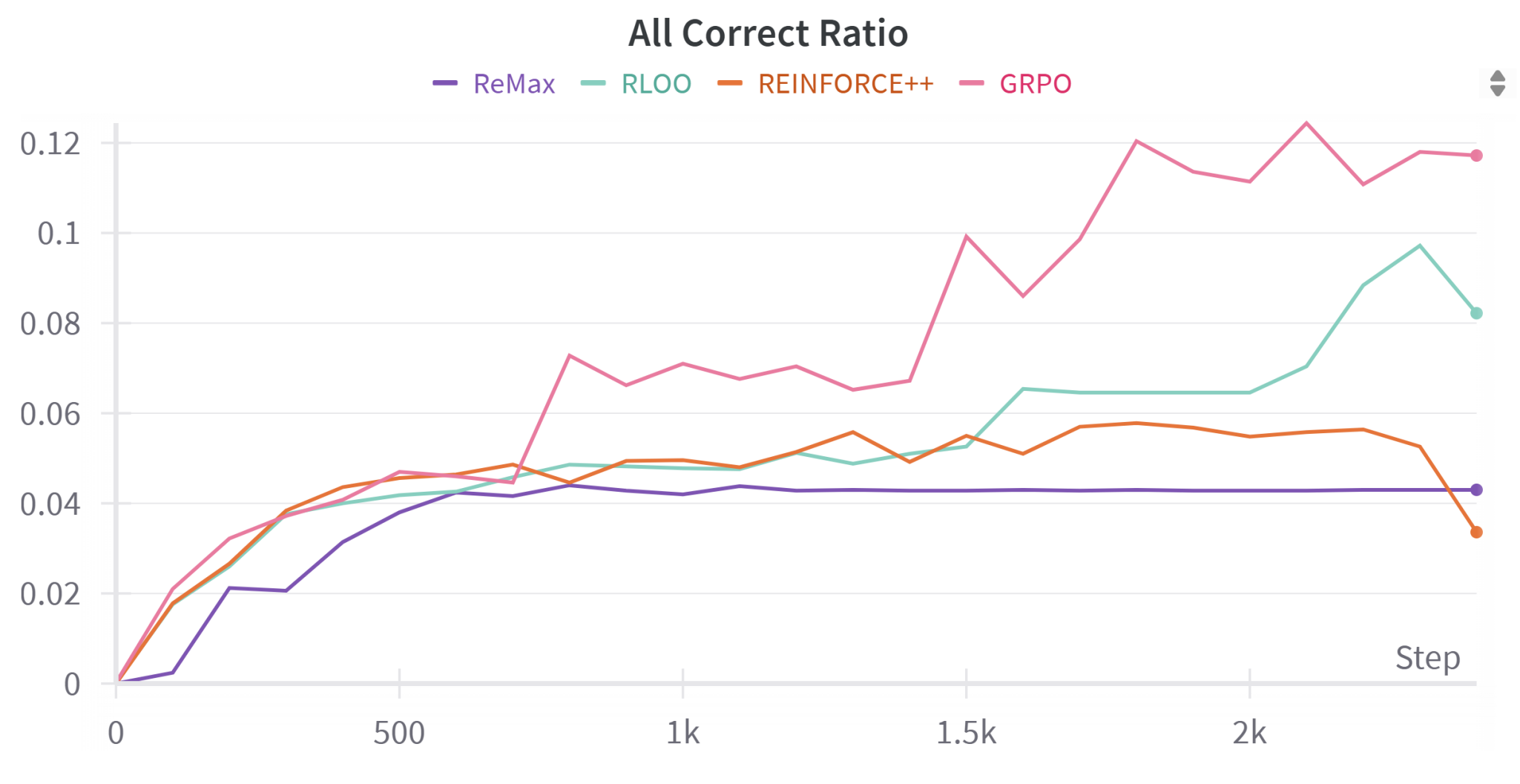
Efficient Consumption Resource



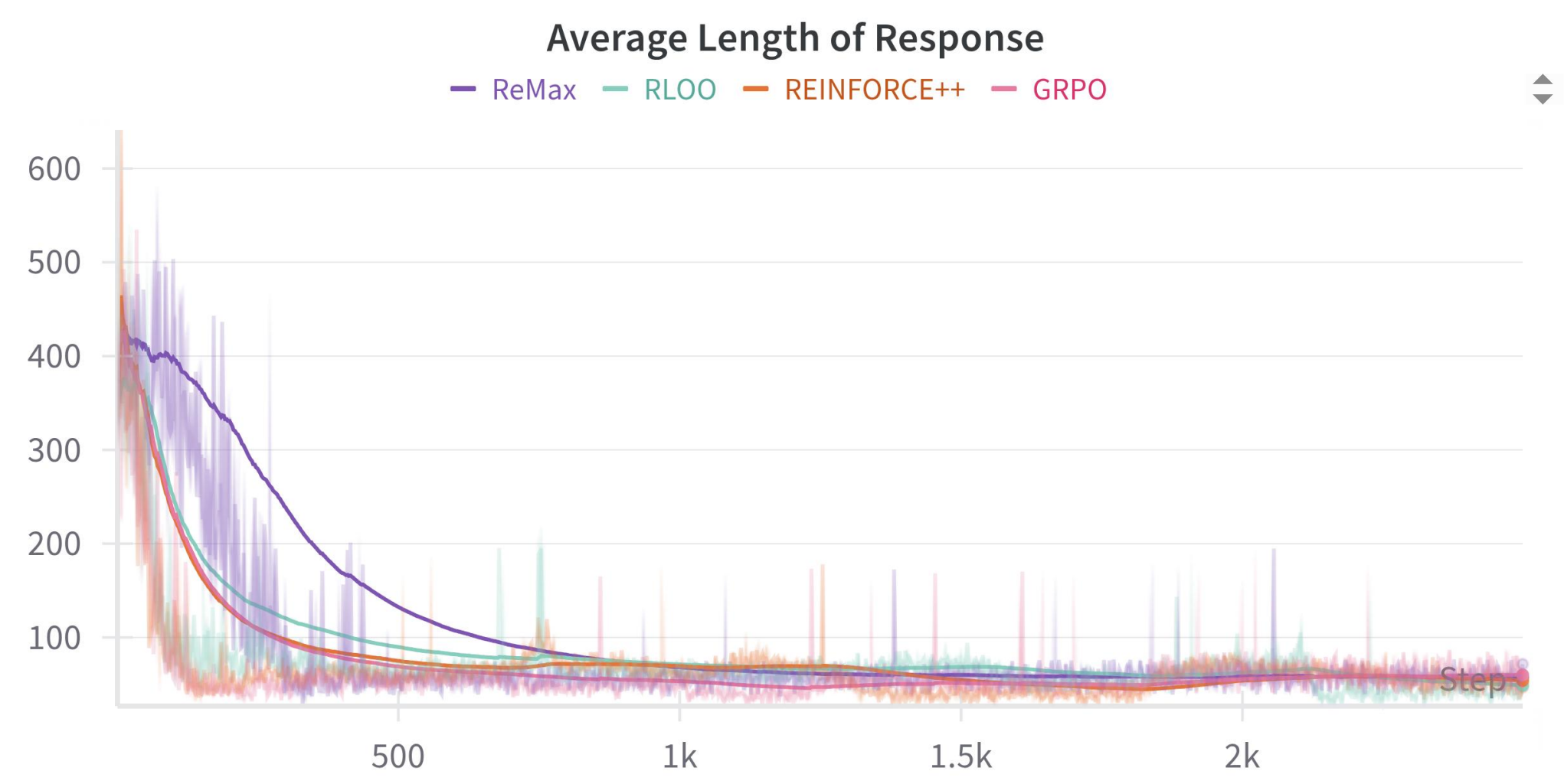


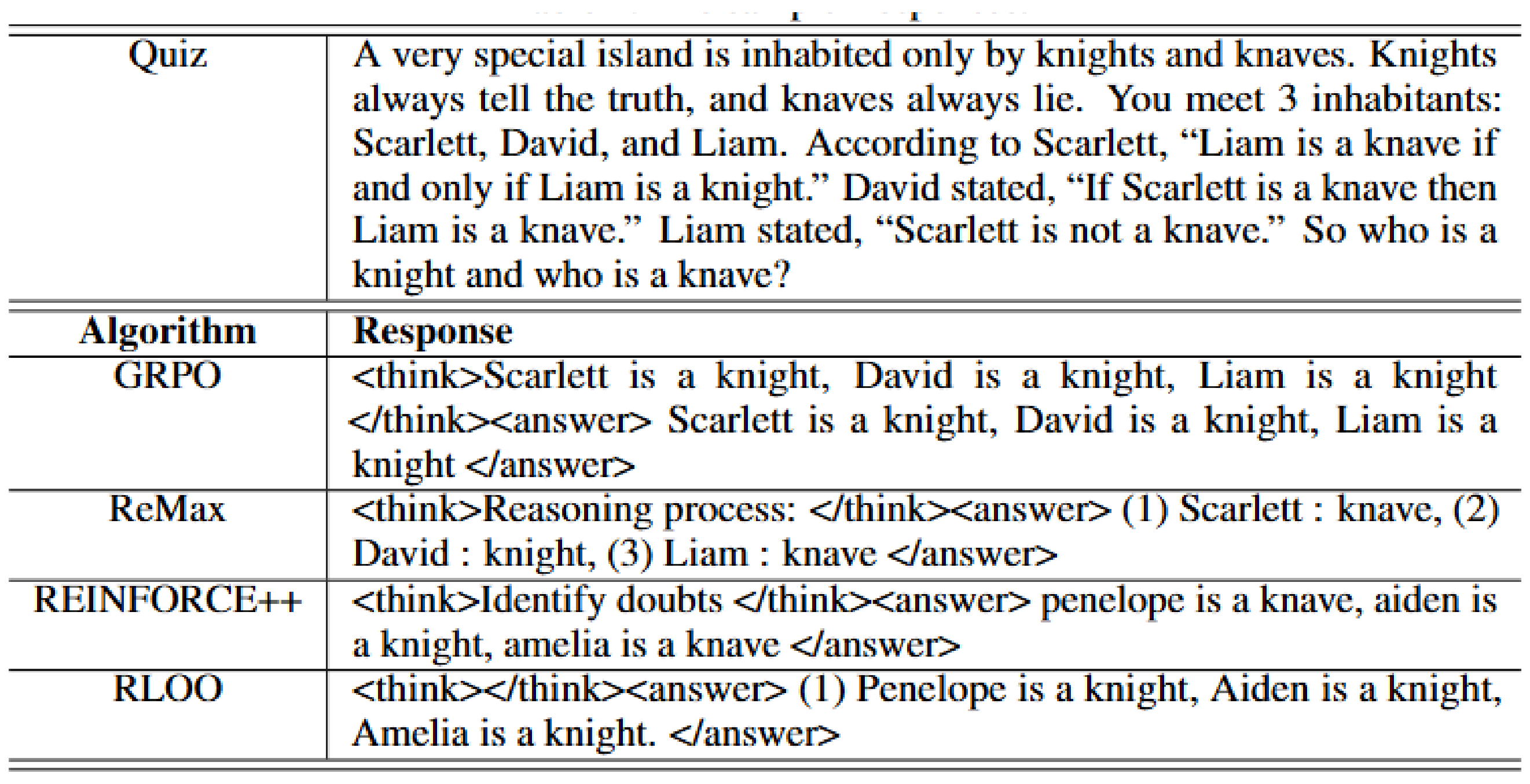
Poor Reasoning Capacity





Is Format Reward a Blessing or a Curse?





Quiz	A very special island is inhabited only by knights and knaves. Knights always tell the truth, and knaves always lie. You meet 3 inhabitants: Scarlett, David, and Liam. According to Scarlett, "Liam is a knave if and only if Liam is a knight." David stated, "If Scarlett is a knave then Liam is a knave." Liam stated, "Scarlett is not a knave." So who is a knight and who is a knave?
Algorithm	**Response**
GRPO	<think>Scarlett is a knight, David is a knight, Liam is a knight </think><answer> Scarlett is a knight, David is a knight, Liam is a knight </answer>
ReMax	<think>Reasoning process: </think><answer> (1) Scarlett : knave, (2) David : knight, (3) Liam : knave </answer>
REINFORCE++	<think>Identify doubts </think><answer> penelope is a knave, aiden is a knight, amelia is a knave </answer>
RLOO	<think></think><answer> (1) Penelope is a knight, Aiden is a knight, Amelia is a knight. </answer>

- Whether small-scale models possess reasoning capabilities?
- What kind of rewards should we design to elicit reasoning from small-scale models?

identifying and rewarding certain thinking tokens