Do As I Can, Not As I Say: Grounding Language in Robotic Affordance

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LLM has no experience, but has knowledge

Robot has no knowledge, but has experience

LLM Say knowledge

+

Robot Can do experience

||

SayCan

SayCan is to ground large language models through value functions——affordance functions that capture the log likelihood that a particular skill will be able to succeed in the current state.

Methodology

- i： Instruction

  How would you put an apple on the table?

- π： action in Robot action space

  l_π ：action natural language description

  Find an apple

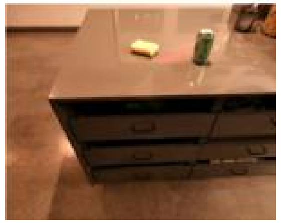
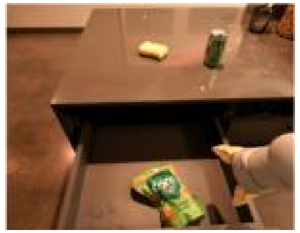
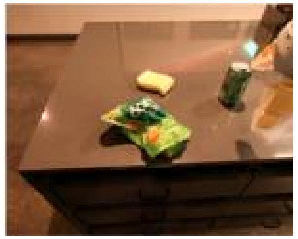
  Find a coke

  Pick up the apple

  Place the apple

  . . . . . .

- s： environment state

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Gripper Height

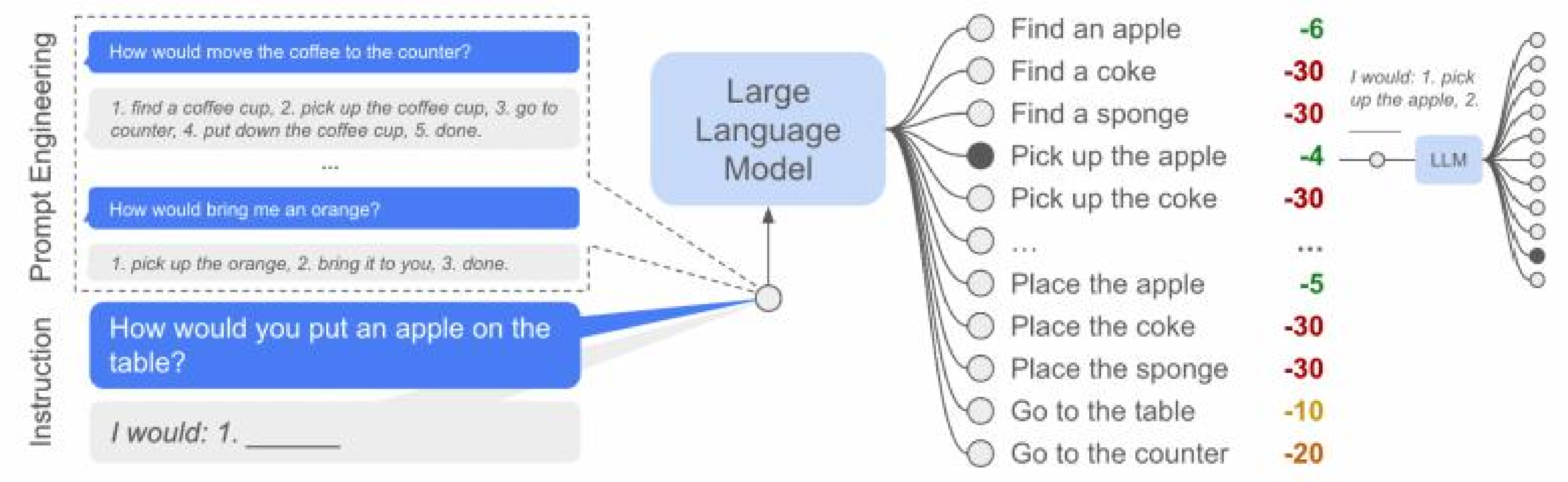
Rotation to Go

Closure to Go

. . . . . .

Methodology

LLM provides $p(l_\pi|i)$



How would move the coffee to the counter?

1. find a coffee cup, 2. pick up the coffee cup, 3. go to counter, 4. put down the coffee cup, 5. done.

...

How would bring me an orange?

1. pick up the orange, 2. bring it to you, 3. done.

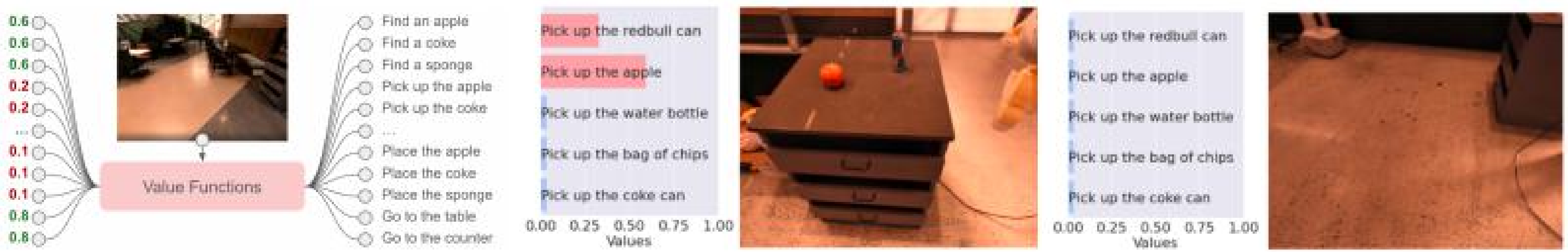
How would you put an apple on the table?

I would: 1. ______

○ Find an apple	-6
○ Find a coke	-30
○ Find a sponge	-30
● Pick up the apple	-4
○ Pick up the coke	-30
○ ...	...
○ Place the apple	-5
○ Place the coke	-30
○ Place the sponge	-30
○ Go to the table	-10
○ Go to the counter	-20

Methodology

Agent（Robot， etc）provides $p(c_\pi|l_\pi, s)$

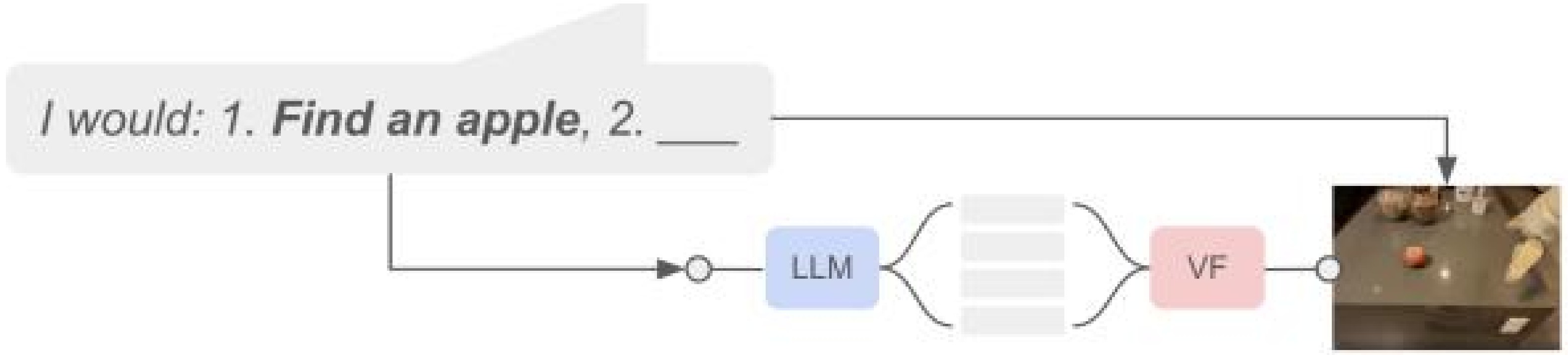


(a) (b) (c)

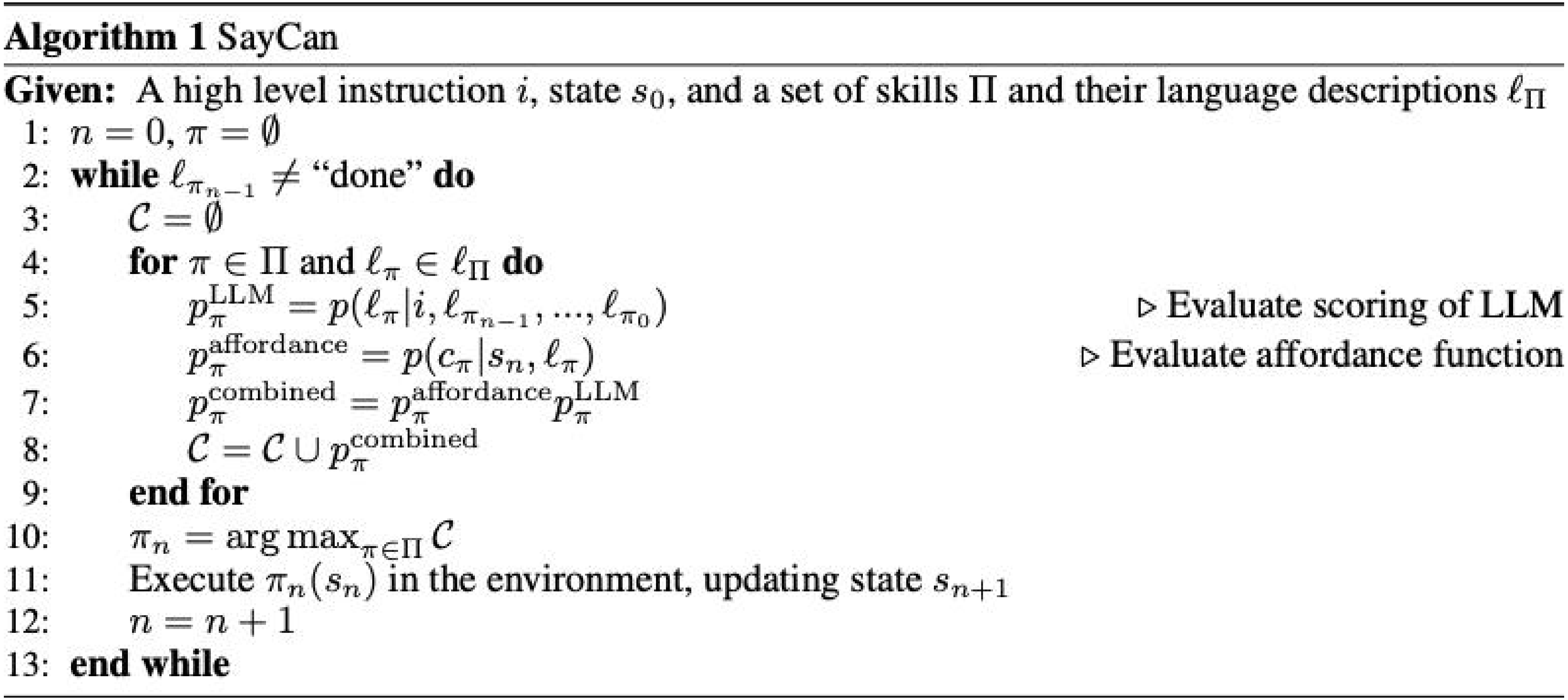
Methodology

$$p(c_\pi | i, s, l_\pi) \propto p(l_\pi | i) p(c_\pi | l_\pi, s)$$

$$\pi = \arg\max_{\pi \in \prod} p(l_\pi | i) p(c_\pi | l_\pi, s)$$



Methodology



Algorithm 1 SayCan

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Given: A high level instruction $i$, state $s_0$, and a set of skills $\Pi$ and their language descriptions $\ell_\Pi$
$n = 0, \pi = \emptyset$
while $\ell_{\pi_{n-1}} \neq$ "done" do
    $\mathcal{C} = \emptyset$
    for $\pi \in \Pi$ and $\ell_\pi \in \ell_\Pi$ do
        $p_\pi^{\text{LLM}} = p(\ell_\pi | i, \ell_{\pi_{n-1}}, ..., \ell_{\pi_0})$        ▷ Evaluate scoring of LLM
        $p_\pi^{\text{affordance}} = p(c_\pi | s_n, \ell_\pi)$        ▷ Evaluate affordance function
        $p_\pi^{\text{combined}} = p_\pi^{\text{affordance}} p_\pi^{\text{LLM}}$
        $\mathcal{C} = \mathcal{C} \cup p_\pi^{\text{combined}}$
    end for
    $\pi_n = \arg\max_{\pi \in \Pi} \mathcal{C}$
    Execute $\pi_n(s_n)$ in the environment, updating state $s_{n+1}$
    $n = n + 1$
end while
```

Model architecture——Agent

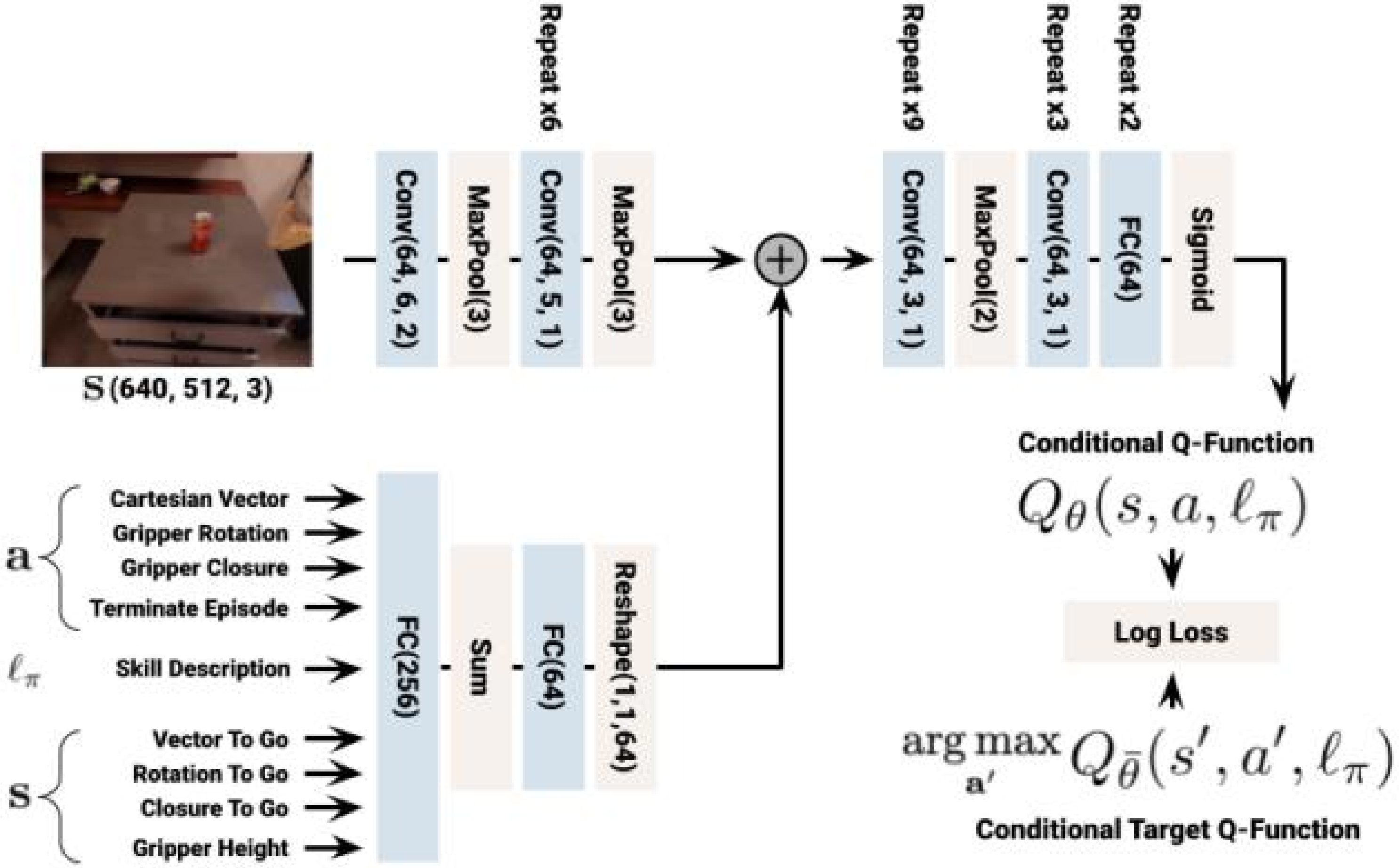


Figure 9: Network architecture in RL policy

《Mt—opt：Continuous multi—task robotic reinforcement learning at scale》

Model architecture——Agent

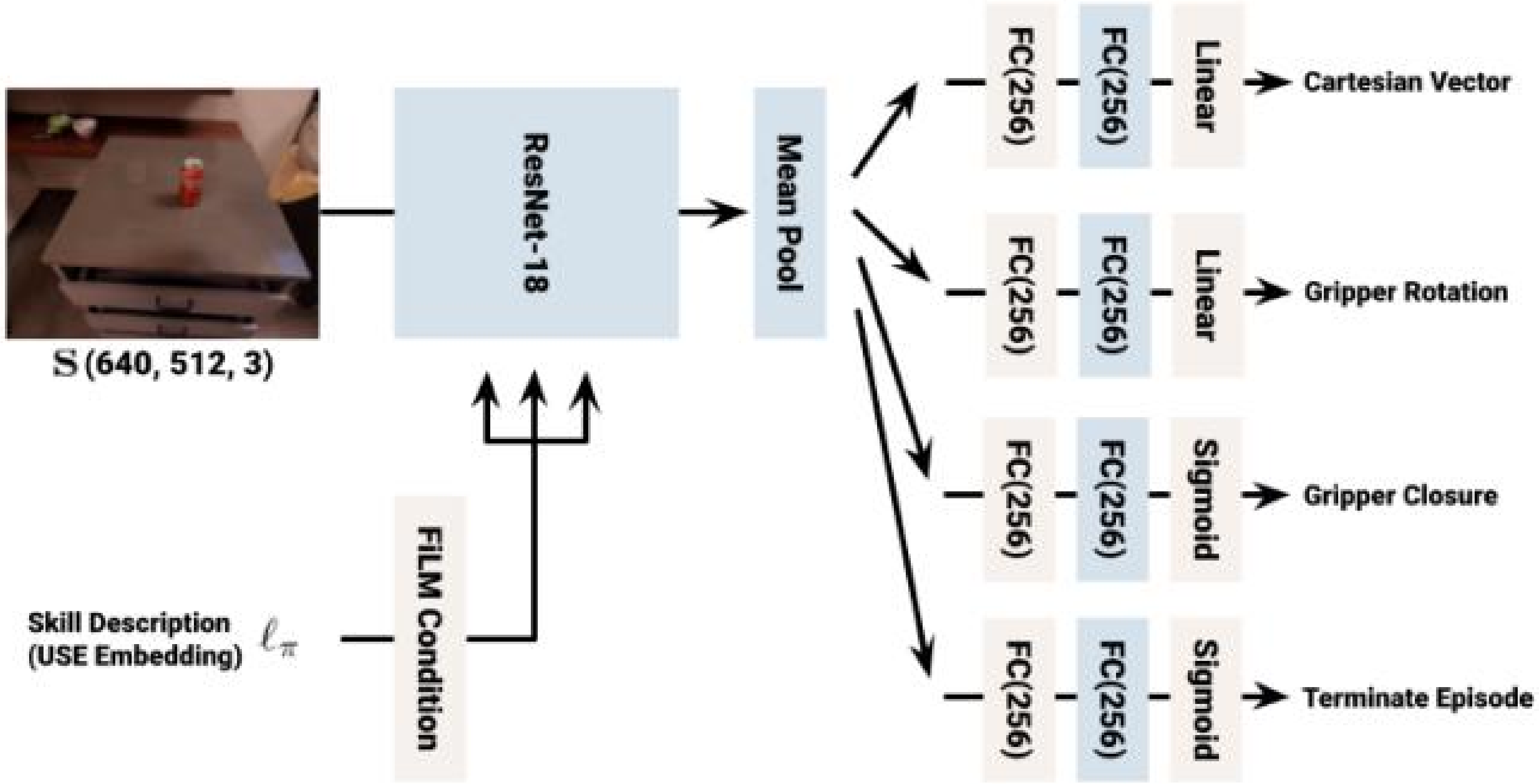


Figure 10: Network architecture in BC policy

《Bc—z：Zero—shot task generalization with robotic imitation learning》

Model architecture——Agent

expert DM data: $\{T_1, T_2, T_3, \dots T_n\}$

$T_i = \langle s_1^i, a_1^i, s_2^i, a_2^i, \dots \dots s_T^i, a_T^i \rangle$

$\Downarrow$

$D = \{(s_1^i, a_1^i), (s_2^i, a_2^i), \dots \}$

$\Downarrow$

$\boxed{\text{classifier}}$

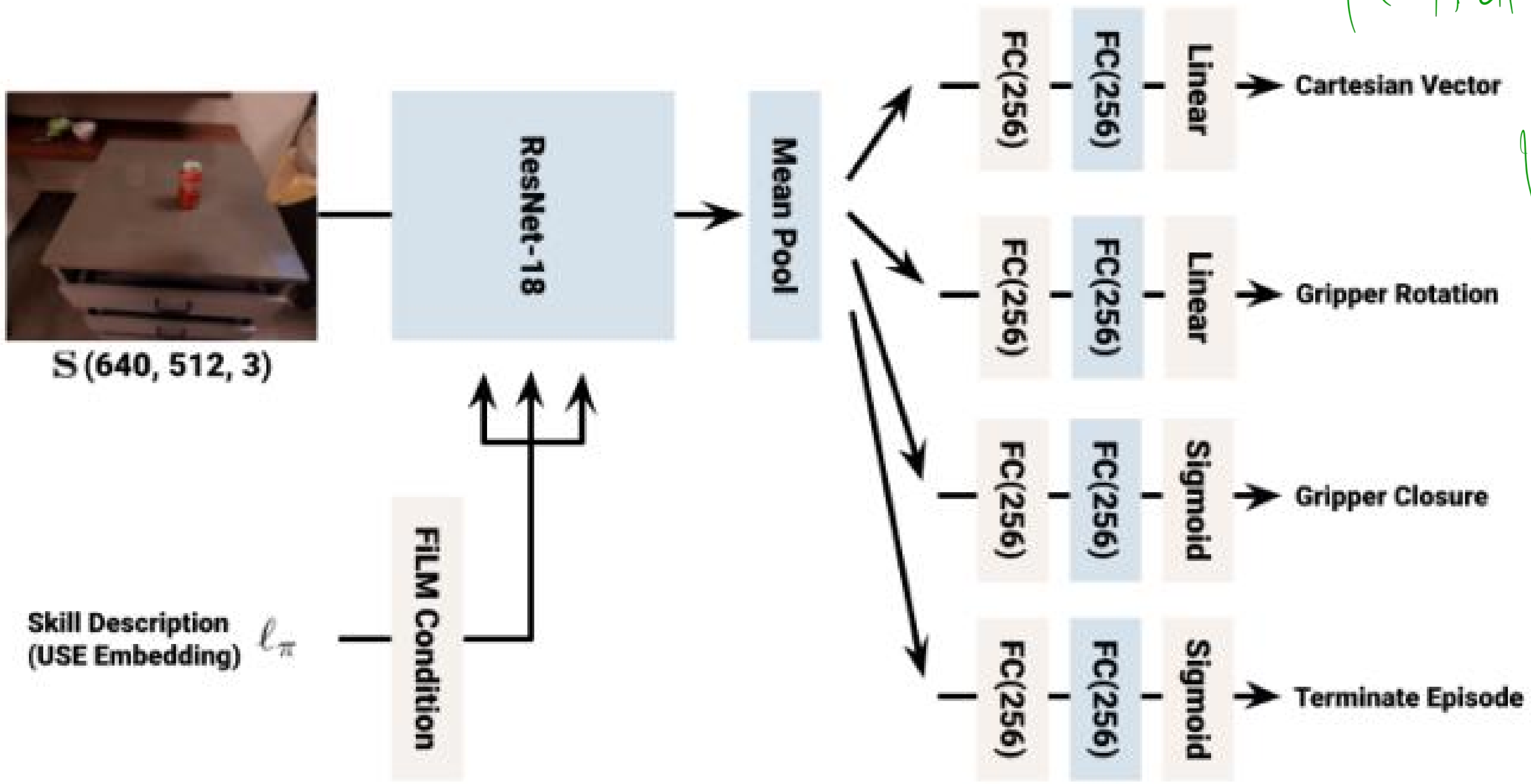


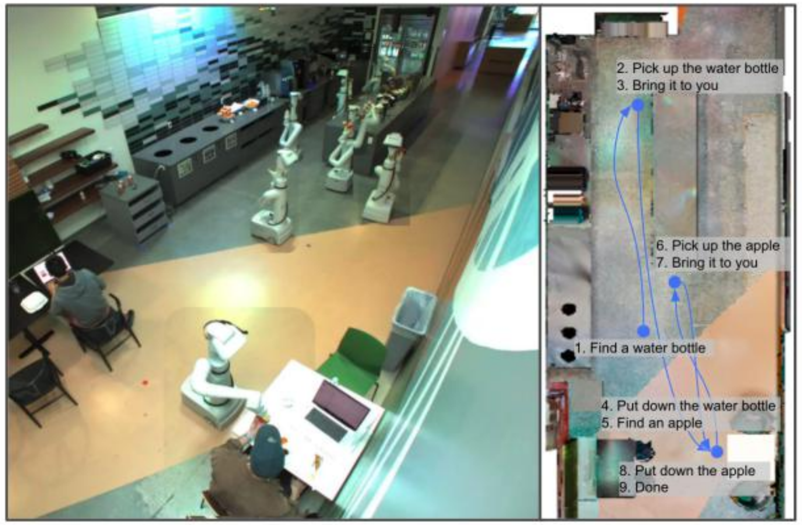
Figure 10: Network architecture in BC policy

《Bc—z：Zero—shot task generalization with robotic imitation learning》

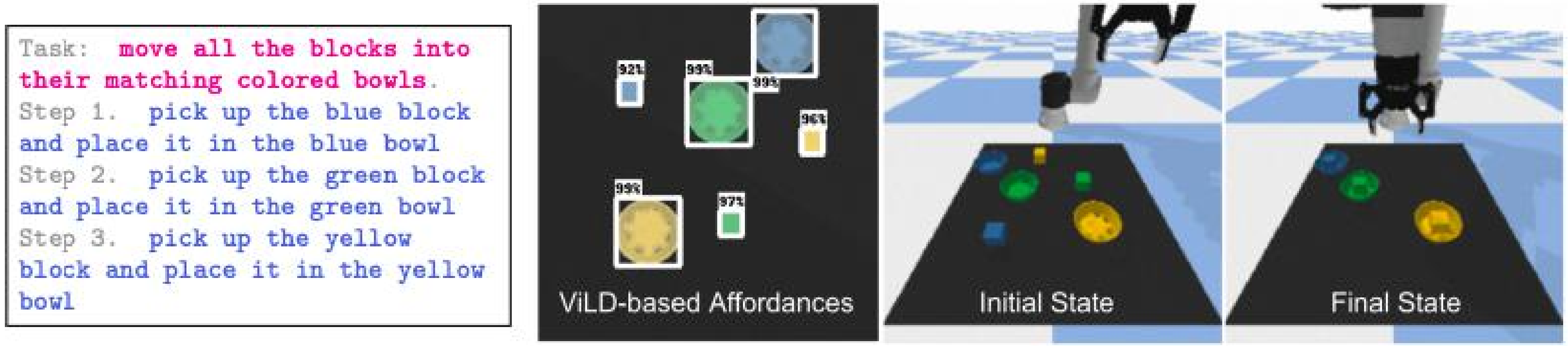
Model architecture——LLM

- PaLM 《PaLM：Scaling Language Modeling with Pathways》
- FLAN 《FINETUNED LANGUAGE MODELS ARE ZERO—SHOT LEARNERS》

Experiment/Result

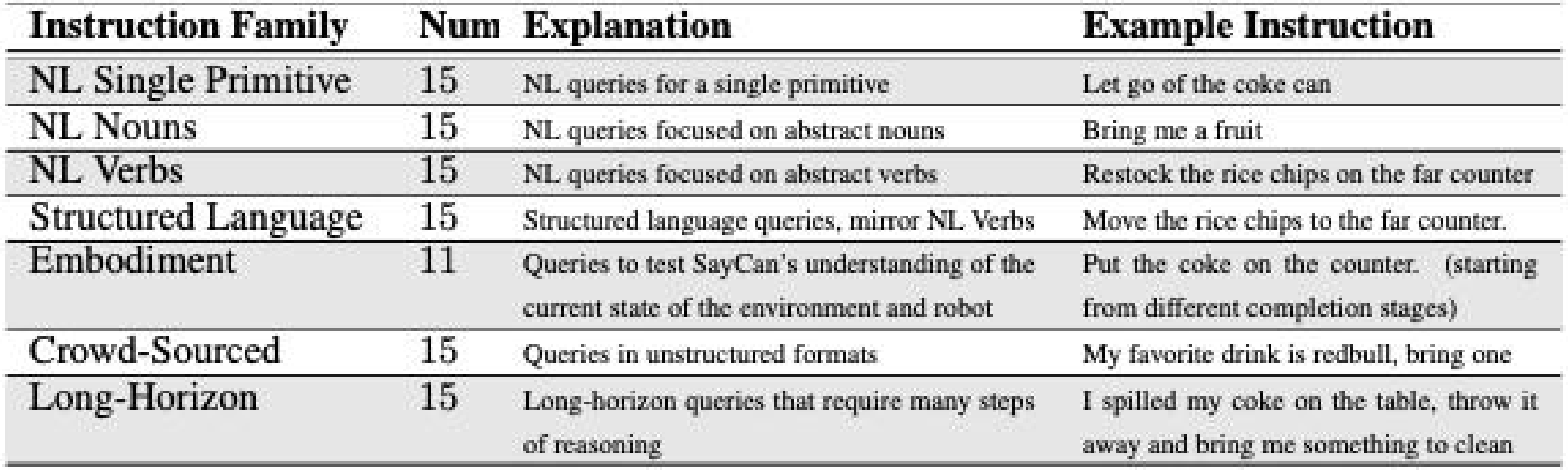


(a) "I just worked out, can you bring me a drink and a snack to recover?"

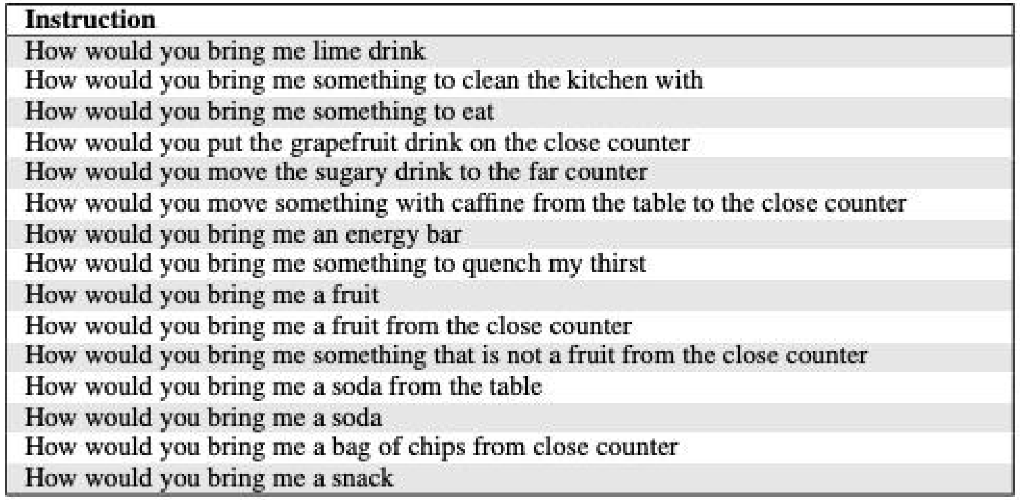


Task: move all the blocks into their matching colored bowls.
Step 1. pick up the blue block and place it in the blue bowl
Step 2. pick up the green block and place it in the green bowl
Step 3. pick up the yellow block and place it in the yellow bowl

Experiment/Result

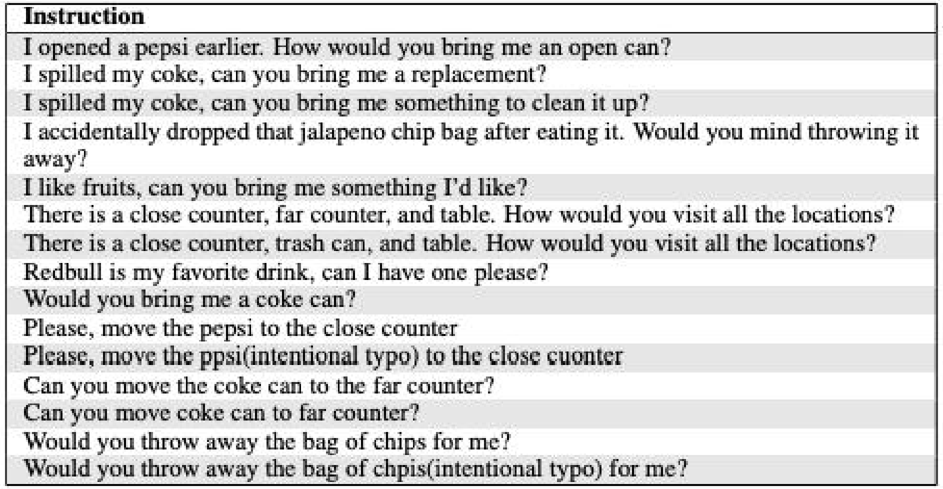


Instruction Family	Num	Explanation	Example Instruction
NL Single Primitive	15	NL queries for a single primitive	Let go of the coke can
NL Nouns	15	NL queries focused on abstract nouns	Bring me a fruit
NL Verbs	15	NL queries focused on abstract verbs	Restock the rice chips on the far counter
Structured Language	15	Structured language queries, mirror NL Verbs	Move the rice chips to the far counter.
Embodiment	11	Queries to test SayCan's understanding of the current state of the environment and robot	Put the coke on the counter. (starting from different completion stages)
Crowd-Sourced	15	Queries in unstructured formats	My favorite drink is redbull, bring one
Long-Horizon	15	Long-horizon queries that require many steps of reasoning	I spilled my coke on the table, throw it away and bring me something to clean



Instruction
How would you bring me lime drink
How would you bring me something to clean the kitchen with
How would you bring me something to eat
How would you put the grapefruit drink on the close counter
How would you move the sugary drink to the far counter
How would you move something with caffine from the table to the close counter
How would you bring me an energy bar
How would you bring me something to quench my thirst
How would you bring me a fruit
How would you bring me a fruit from the close counter
How would you bring me something that is not a fruit from the close counter
How would you bring me a soda from the table
How would you bring me a soda
How would you bring me a bag of chips from close counter
How would you bring me a snack

(c) NL Nouns



Instruction
I opened a pepsi earlier. How would you bring me an open can?
I spilled my coke, can you bring me a replacement?
I spilled my coke, can you bring me something to clean it up?
I accidentally dropped that jalapeno chip bag after eating it. Would you mind throwing it away?
I like fruits, can you bring me something I'd like?
There is a close counter, far counter, and table. How would you visit all the locations?
There is a close counter, trash can, and table. How would you visit all the locations?
Redbull is my favorite drink, can I have one please?
Would you bring me a coke can?
Please, move the pepsi to the close counter
Please, move the ppsi(intentional typo) to the close cuonter
Can you move the coke can to the far counter?
Can you move coke can to far counter?
Would you throw away the bag of chips for me?
Would you throw away the bag of chpis(intentional typo) for me?

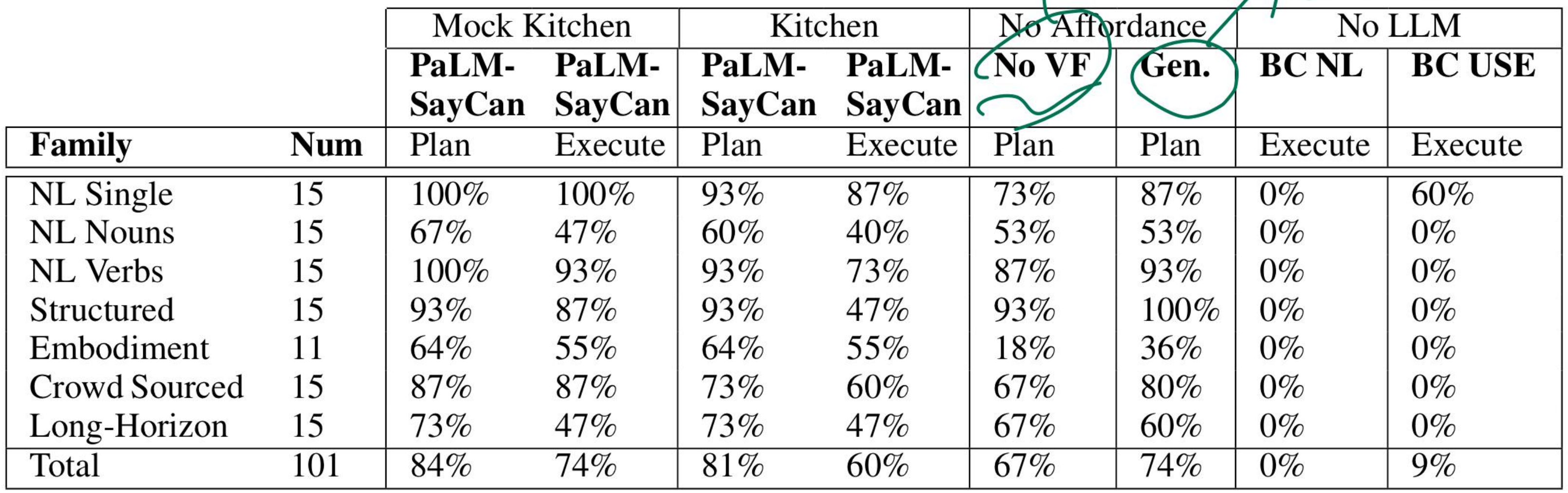
(f) Crowd-Sourced

Experiment/Result

- plan success rate
- execution success rate

no value function

Generative



		Mock Kitchen		Kitchen		No Affordance		No LLM	
		PaLM-SayCan	**PaLM-SayCan**	**PaLM-SayCan**	**PaLM-SayCan**	**No VF**	**Gen.**	**BC NL**	**BC USE**
Family	**Num**	Plan	Execute	Plan	Execute	Plan	Plan	Execute	Execute
NL Single	15	100%	100%	93%	87%	73%	87%	0%	60%
NL Nouns	15	67%	47%	60%	40%	53%	53%	0%	0%
NL Verbs	15	100%	93%	93%	73%	87%	93%	0%	0%
Structured	15	93%	87%	93%	47%	93%	100%	0%	0%
Embodiment	11	64%	55%	64%	55%	18%	36%	0%	0%
Crowd Sourced	15	87%	87%	73%	60%	67%	80%	0%	0%
Long-Horizon	15	73%	47%	73%	47%	67%	60%	0%	0%
Total	101	84%	74%	81%	60%	67%	74%	0%	9%

What to do next?

Sparse reward!

No middle-step reward!

What to do next?

Sparse reward!

No middle-step reward!

human: How would you put an apple on the table?

robot: ① Go to the counter → Find the apple → Pick up the apple → Go back to the table

Place the apple ⇒ reward: +1

② Go to the counter → Find the apple → Pick up the apple → Pick up the apple ...

Pick up the apple → Pick up the apple → ...... → Pick up the Coak ⇒ reward: 0

Code／Dataset

- https：／／github．com／google－research／google－research／tree／master／saycan
- https：／／github．com／say－can／say－can．github．io／tree／main／data