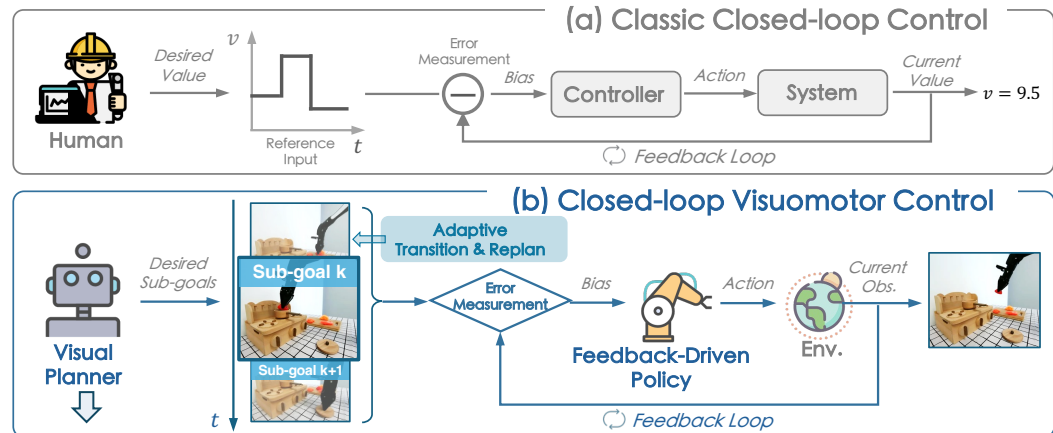


# CLOsed-loop Visuomotor Control with Generation Expectation for Robotic Manipulation



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## What do we want to build?



## How does CLOVER work?

### Algorithm 1: CLOVER: Test-time Execution

**Input:** Visual planner  $p_\theta$ ; Policy  $\pi_\phi$ ; State encoding module  $g_\phi(\cdot)$ ; Cosine distance  $D_C(\cdot, \cdot)$ .  
**Hyper parameters:** Time limit  $T$ ; Distance threshold for replan and sub-goal transition  $\{D_R, D_S\}$ .

```

1  $t \leftarrow 0, i_{sub} \leftarrow 0$ 
2 while  $t \leq T$  do
3   if Replan or  $t == 0$  then
4      $\hat{O}_{1:K} \sim p_\theta(O_{1:K} | O_0, c_t)$ 
5     if  $\max_{k=1, \dots, K-1} \{D_C(g_\phi(\hat{O}_k), g_\phi(\hat{O}_{k+1}))\} > D_R$  then
6       Replan  $\leftarrow$  True
7     else
8       Replan  $\leftarrow$  False
9     end
10  end
11  if  $D_C(g_\phi(O_0), g_\phi(\hat{O}_{i_{sub}})) < D_S$  then
12     $i_{sub} \leftarrow i_{sub} + 1$ 
13  end
14  Sample and Execute  $\hat{a} \sim \pi_\phi(a_0 | O_0, \hat{O}_{i_{sub}})$ 
15   $O_0 \leftarrow Env(\hat{a})$ 
16   $t \leftarrow t + 1$ 
17 end
    
```

Initialize the sub-goal selection index

Video Diffusion Model

Generate language-conditioned sub-goals (Section 3.1)

Replan if sub-goals are unreachable

Transition if the current sub-goal has been reached

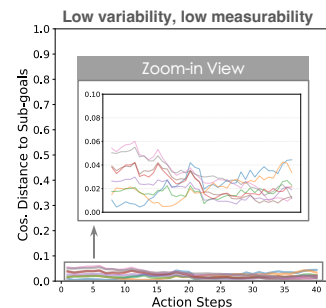
Predict and execute action (Section 3.2)

Update current observation

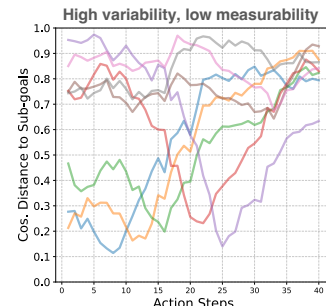
Inverse Dynamics Model

## Key Insight

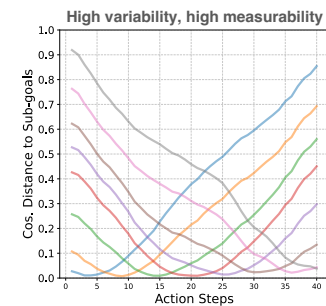
Fig.: Cosine Distance of Current State (Obs.) to eight generated sub-goals



(a) CLIP Feature



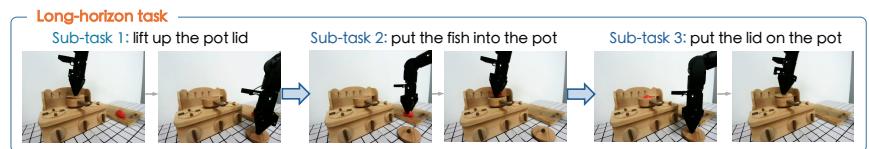
(b) State Embedding w/o Error Measuring



(c) State Embedding (Ours)

Inverse Dynamics objective can inherently learn to measure the distance of states!

## Real-world Robot Experiments



Method	Long-horizon task				Single task	
	Sub-task 1	Sub-task 2	Sub-task 3	Avg. Len. $\uparrow$	Pour shrimp	Stack bowls
ACT [52]	46.7	13.3	0.0	0.6	33.3	46.7
R3M [53]	53.3	20.0	0.0	0.7	46.7	53.3
RT-1 [48]	66.7	40.0	0.0	1.1	80.0	66.7
CLOVER (Ours)	93.3	86.7	26.7	2.1	80.0	86.7

+30%

## Simulation: CALVIN Benchmark

- +8% v.s. 3D Diffuser Actor (previous SOTA)
- +30% v.s. Previous "Planner + Executor" Method (SuSIE)

Method	Type	Train episodes	Task completed in a row (%) $\uparrow$					Avg. Len. $\uparrow$
			1	2	3	4	5	
MCIL [47]	Language-conditioned Behaviour Cloning	All	30.4	1.3	0.2	0.0	0.0	0.31
HULC [48]		All	41.8	16.5	5.7	1.9	1.1	0.67
RT-1 [49]		Lang	53.3	22.2	9.4	3.8	1.3	0.90
RoboFlamingo [50]		Lang	82.4	61.9	46.6	33.1	23.5	2.48
GR-1 [51]		Lang	85.4	71.2	59.6	49.7	40.1	3.06
3D Diffuser Actor [52]	Diffusion Policy	Lang	92.2	78.7	63.9	51.2	41.2	3.27
UniPi* [14]	Planner + Executor	All	56.0	16.0	8.0	8.0	4.0	0.92
SuSIE [15]		All	87.0	69.0	49.0	38.0	26.0	2.69
CLOVER (Ours)		Lang	96.0	83.5	70.8	57.5	45.4	3.53

## Key Ablation: Closed-loop v.s. Open-loop

