

Overcoming Imperfect Kinematics in Surgical Robotics Through Sim-to-Real Visuomotor Learning

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Abstract

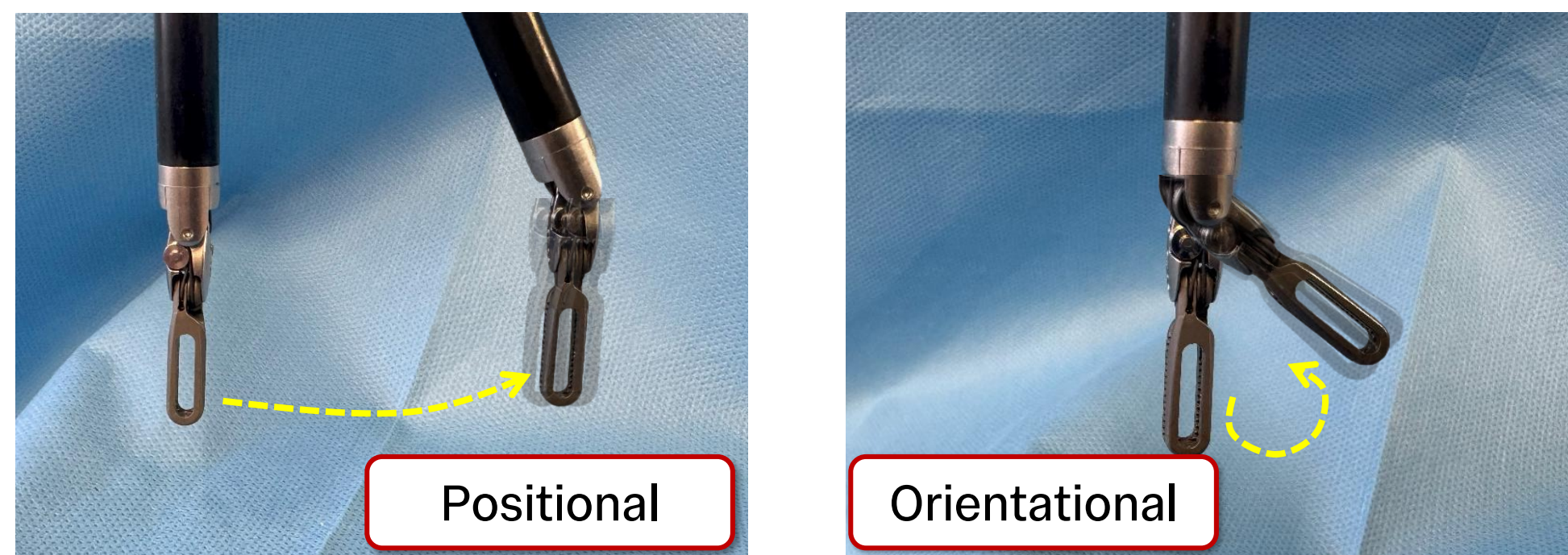
Why?: Imperfect Kinematics is a critical barrier for end-to-end policy learning on surgical robot systems.

How?: We proposed a multi-stage learning pipeline for learning a versatile visuomotor controller.

So?: Robust Sim2Real with spatial and viewpoint generalisation from a single demonstration.

Background

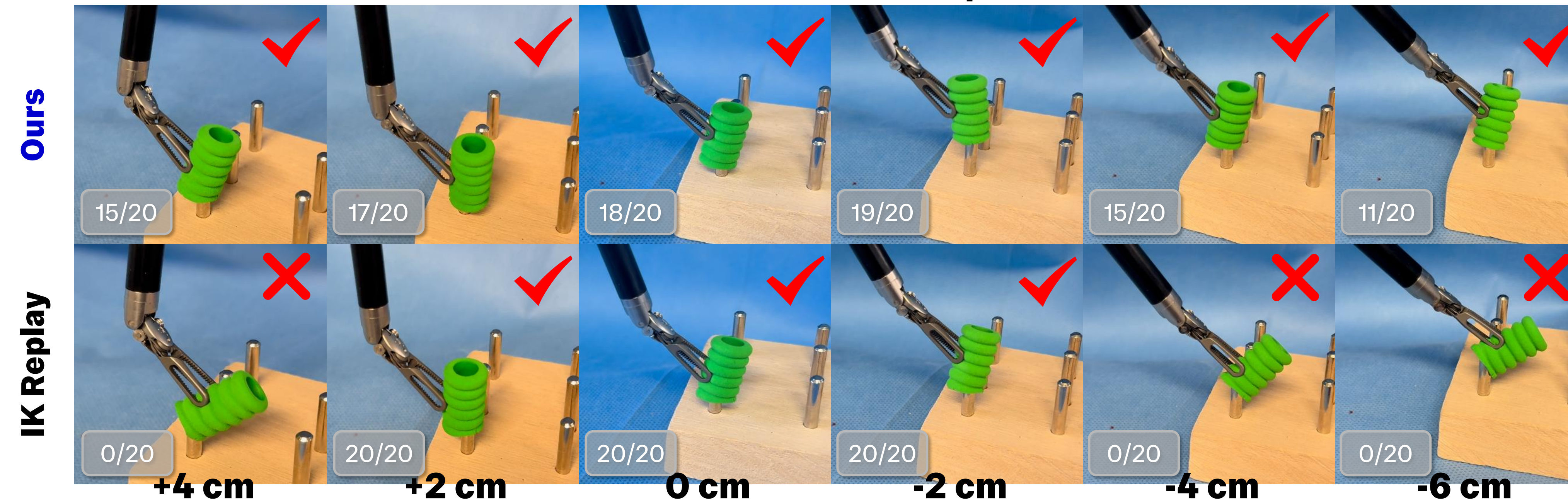
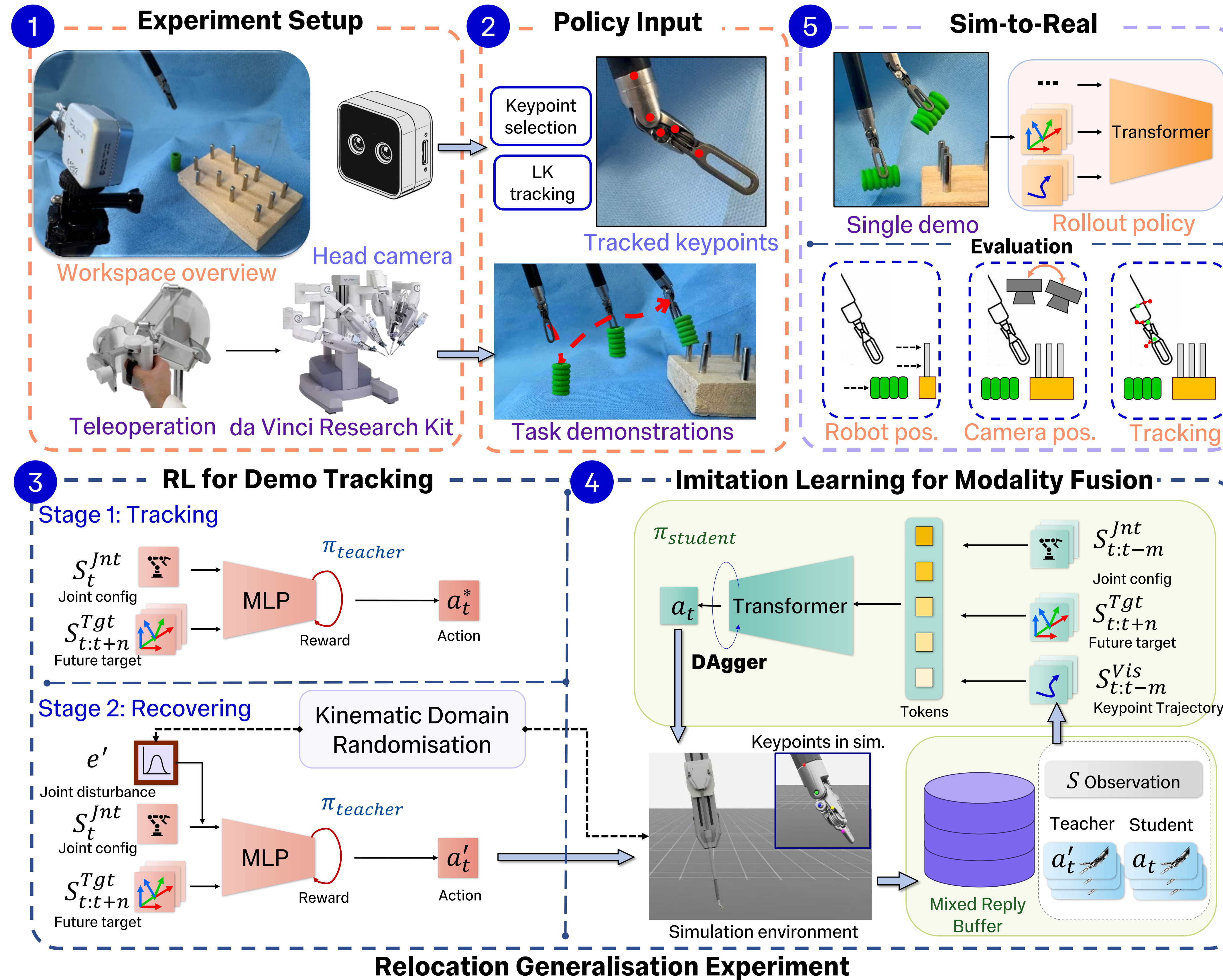
Imperfect Kinematics can cause severe changes on both position and orientation.



Open loop trajectory replay can lead to **0%** success rate even in basic pick-and-place task. Visuomotor controller can form a hierarchical framework with high-level planner to disentangle the kinematic problem in policy learning.

Contributions

1. Multistage training pipeline: **Reinforcement Learning** to enable robust demonstration tracking; **Imitation Learning** to correct kinematic error from visual information.
2. **Sim-to-Real** evaluation on a modified peg transfer task with improved performance.
3. Shows generalisability and robustness as a visuomotor policy for future integration.



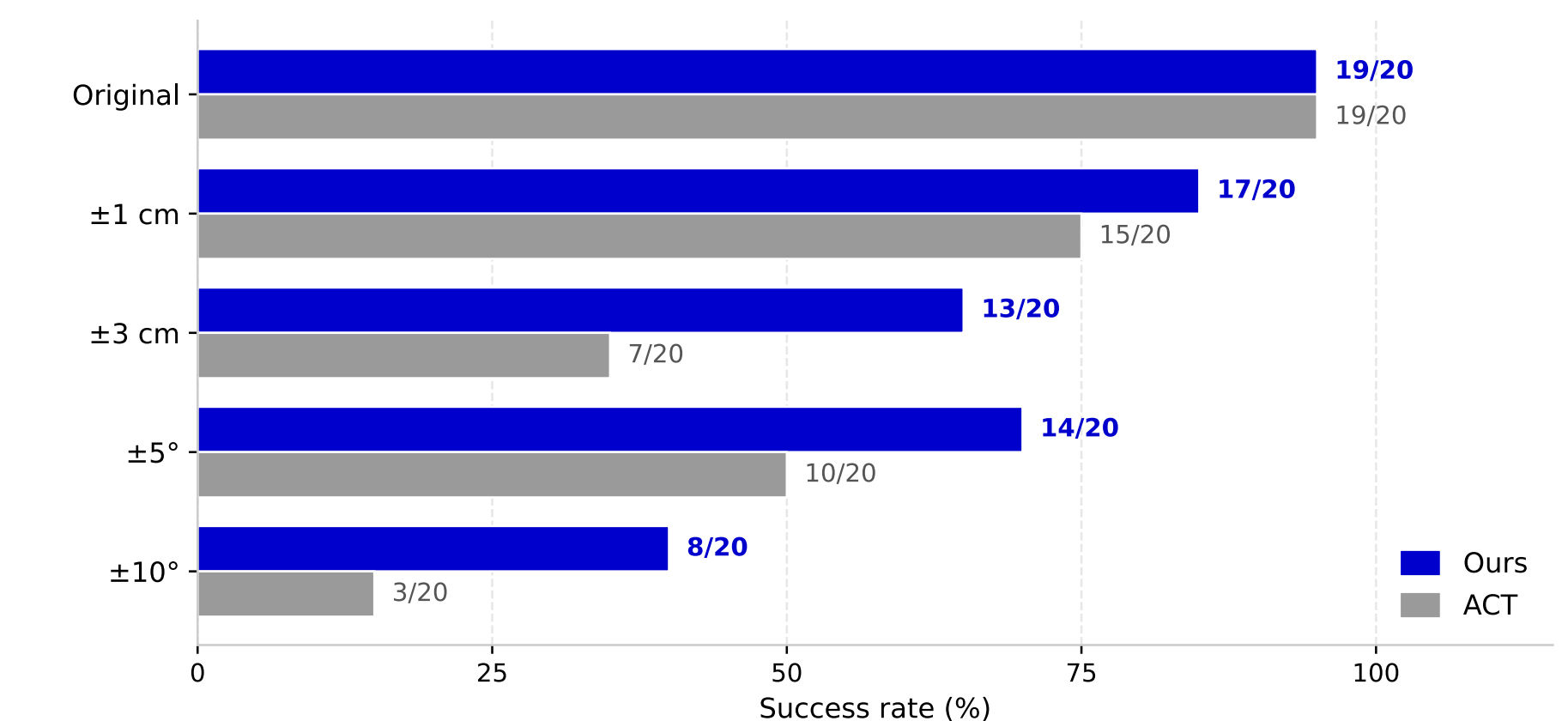
Experiments and Results

Relocation Generalisation

Horizontally shifted the workspace. Compared to replay of a success demo trajectory. ACT completely failed. Proposed method shows better performance at large spatial changes.

Viewpoint Generalisation

Varied camera location and angle. Compared with ACT. Results suggest better robustness to viewpoint change.



Ablation: visual robustness

Added Gaussian noise or ablate tracked key point to investigate its robustness. The policy can tolerate minor defects in tracking. The collapse suggests that the visual information is indeed being considered by the policy.

Method	↑Success Rate				
	Original	Noisy	Drop 2	Drop 4	No access
Ours	9/10	8/10	3/10	0/10	0/10