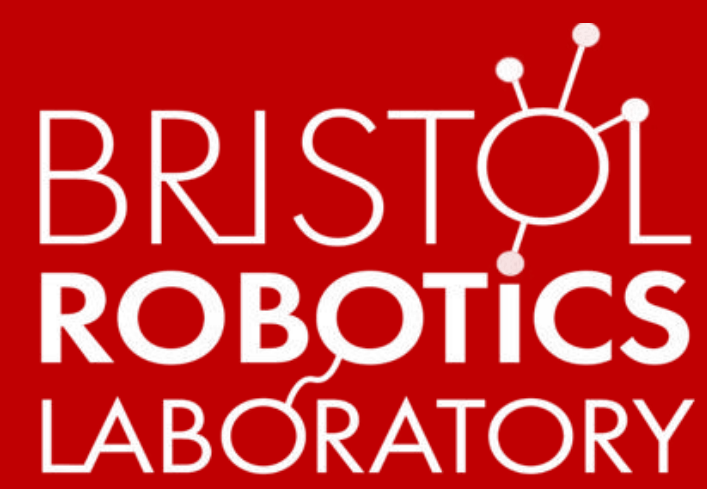


NeuralTouch: Leveraging Implicit Neural Descriptor for Precise Sim-to-Real Tactile Robot Control

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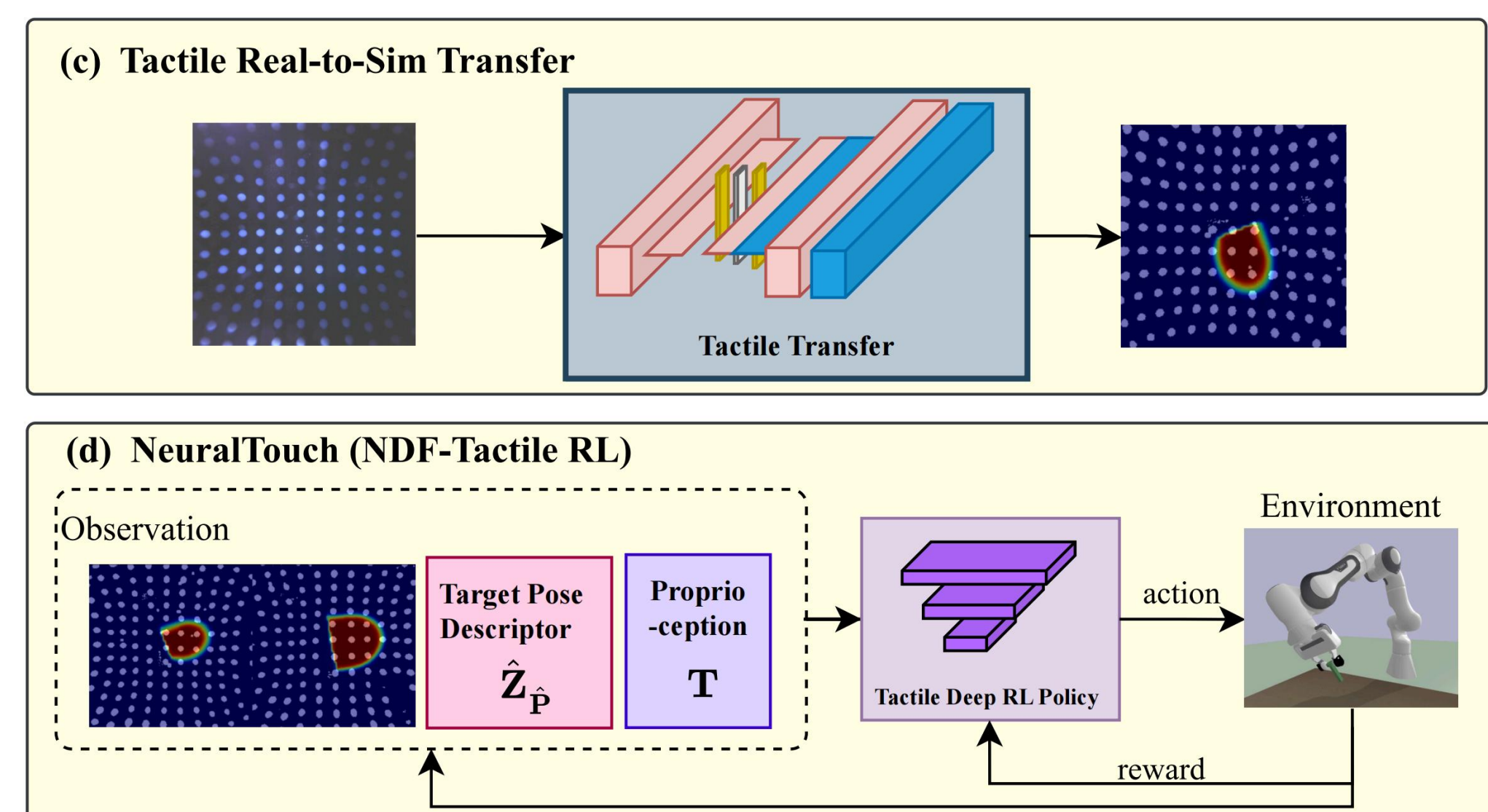
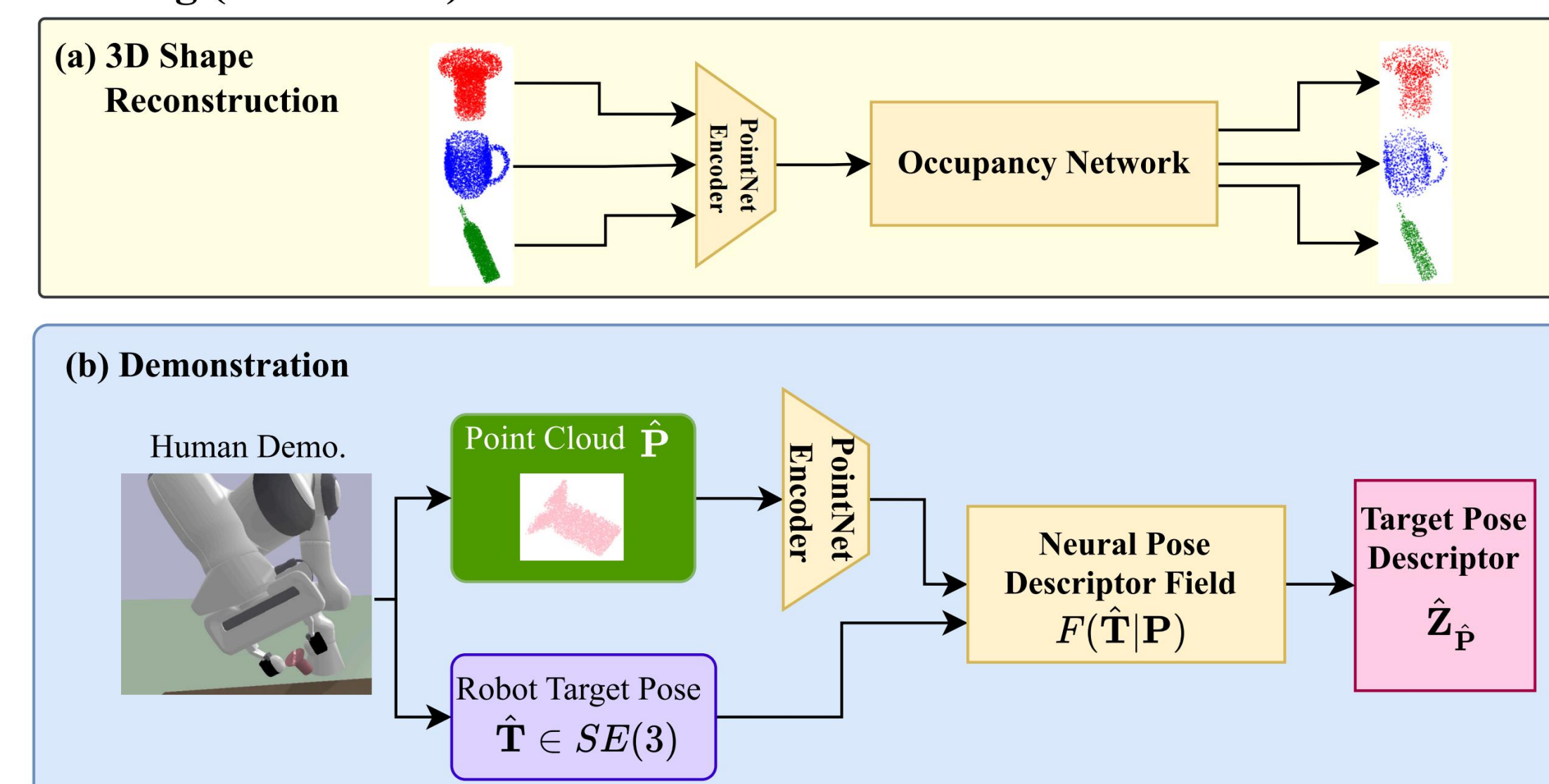
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Introduction

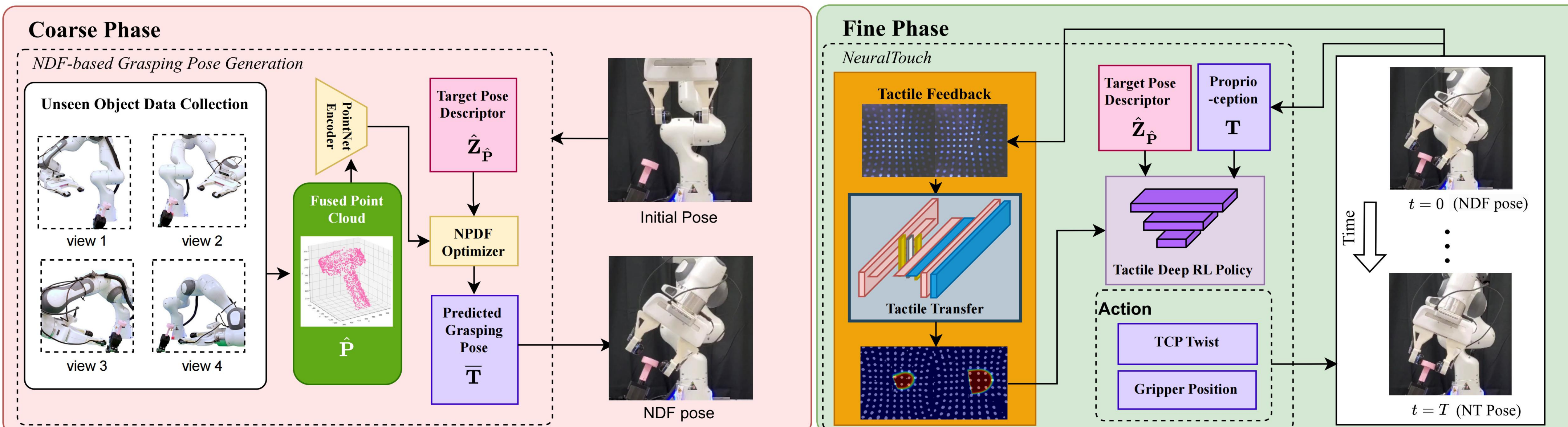
- Grasping accuracy is vital for precise manipulation, requiring alignment between the robotic hand and object. **Neural Descriptor Fields (NDFs)** enable **generalizable robotic grasping** but often yield **inaccuracies** due to depth camera errors, incomplete point clouds, and object variability.
- Recent advances in **robotic touch** offer a promising approach to achieving **accurate grasping**, but most current works focus on learning policies for **limited, predefined, and basic geometric contact patterns**. This hinders robots from adapting to diverse environmental interactions.
- We propose **NeuralTouch**, a framework combining NDFs and tactile sensing to **refine grasping poses** and **develop general tactile policies without relying on specific geometric assumptions**.

Methods

Training (Simulation)

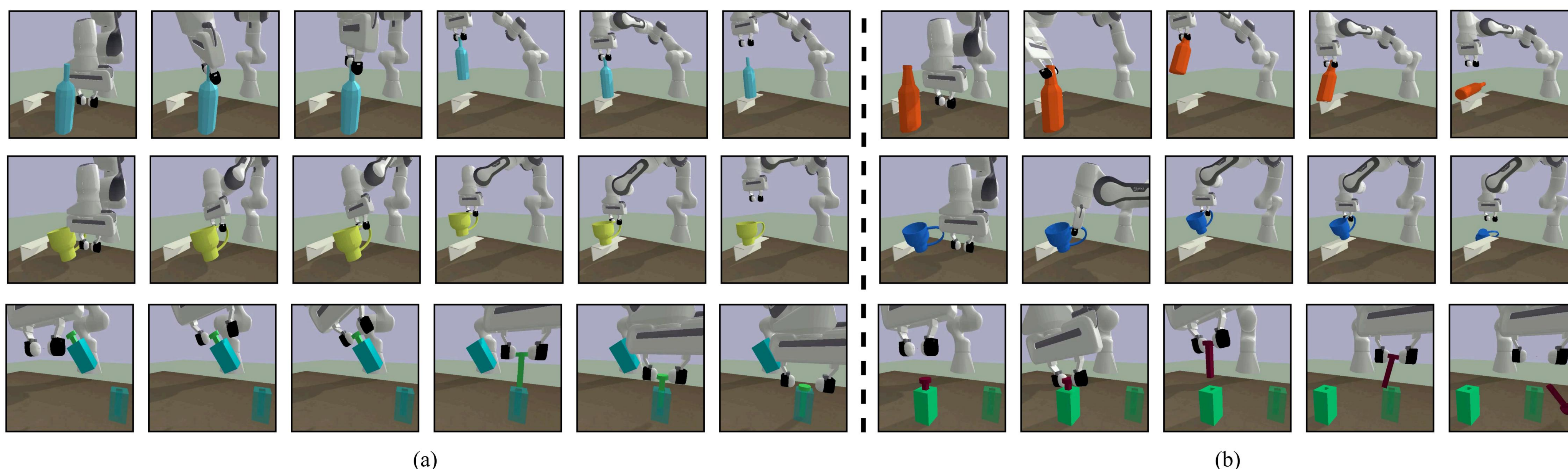


Testing (Real World)

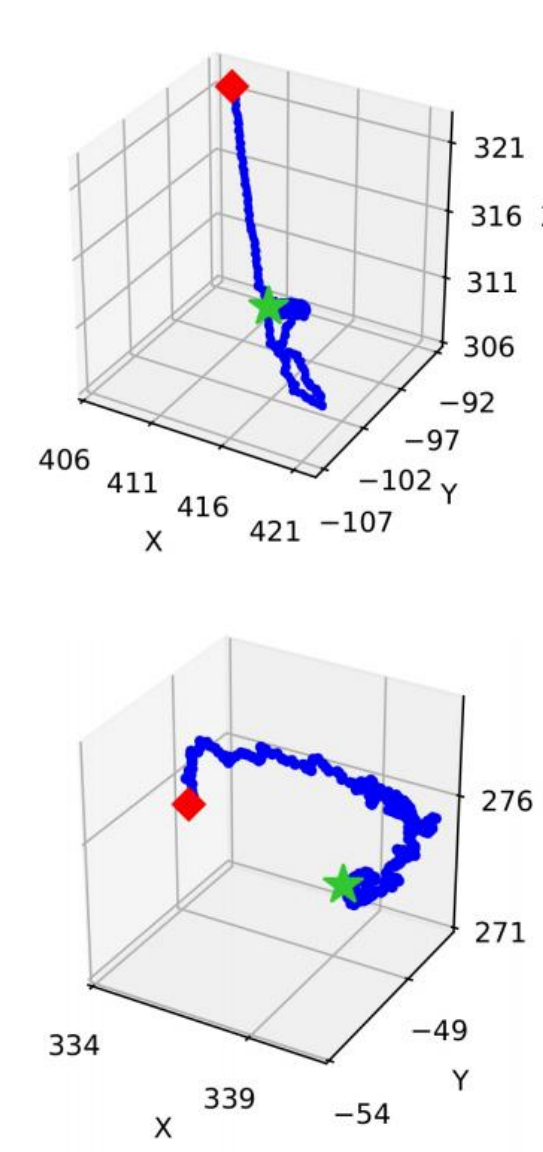
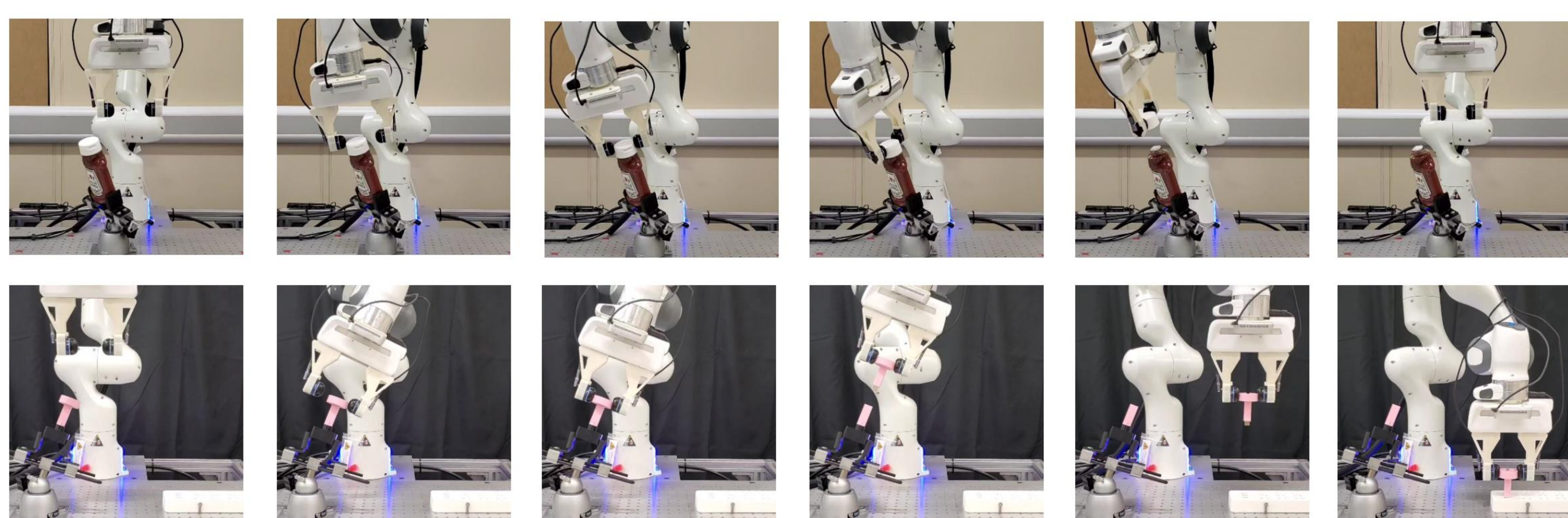


Overview of the NeuralTouch: (a) we first pre-train an occupancy network which is the core component of the Neural Pose Descriptor Fields (NPDF), (b) we collect demonstrations along with object point clouds and robot target grasping pose descriptors depending on the tasks, (c) we train an RL policy with tactile and proprioceptive feedback, to achieve fine grasping poses implicitly specified by these collected descriptors. After obtaining the NPDF and a well-trained policy, our system is directly deployed in the real world with a real-to-sim tactile transfer to accurately grasp unseen objects, executing manipulation tasks such as unplugging a bolt-like USB and inserting it into a socket.

Simulation and Real-world Experiments



The snapshots of the robot performing four different tasks in simulation with three methods: (a) NeuralTouch, (b) NDFs (first row) and NDFs+RL-Touch (last two rows). From the top row to the bottom row in each sub-figure: object-pick-and-place (mug handle, and bottle lid) and peg-out/in-hole.



A Franka Panda arm equipped with a tactile gripper performed two real-world manipulation tasks requiring high accuracy: bottle-lid opening and peg-in/out-hole insertion. The plots in the final column depict the end-effector trajectories recorded during the second phase. The red diamond represents the initial position determined by NDFs, while the green star indicates the final position achieved after tactile servoing.

Contributions

- We propose a deep-RL-based framework with neural descriptor fields to train a general tactile policy which does not need any explicit assumption about the contact patterns beforehand.
- We demonstrate that our NeuralTouch can serve as a strong complement to the state-of-the-art vision-based grasping method to achieve the desired grasping pose with higher accuracy.
- We also conduct sufficient experiments with zero-shot sim-to-real policy transfer and few-shot demonstration to showcase that our method is able to solve different downstream tasks of different objects in the real world.

References

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- Y. Lin, J. Lloyd, A. Church and N. F. Lepora, "Tactile Gym 2.0: Sim-to-Real Deep Reinforcement Learning for Comparing Low-Cost High-Resolution Robot Touch," in IEEE Robotics and Automation Letters, vol. 7, no. 4, pp. 10754-10761, Oct. 2022