Data-Efficient Representation Learning for Grasping and Manipulation

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Motivation

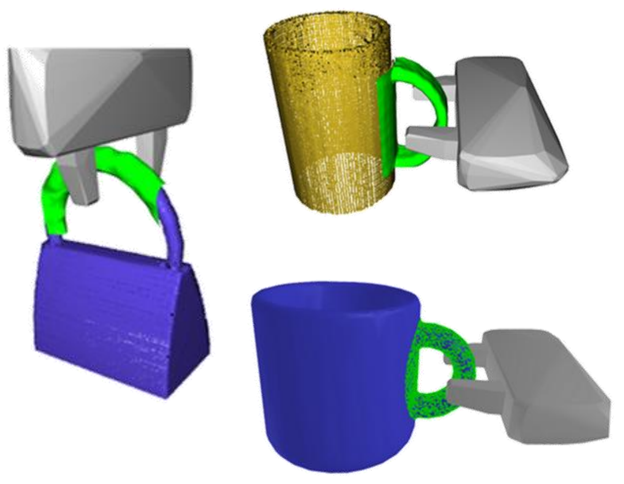
- We focus on data-efficient learning of scene and motion representations to address the challenges in learning from real data that is sparse, and uncertain[1].
- We study how to best represent objects, environments, and actions to achieve robot manipulation tasks learning from minimal amount of data.

[1] Dulac-Arnold, Gabriel, et al. "Challenges of real-world reinforcement learning: definitions, benchmarks and analysis." *Machine Learning* 110.9 (2021): 2419-2468.

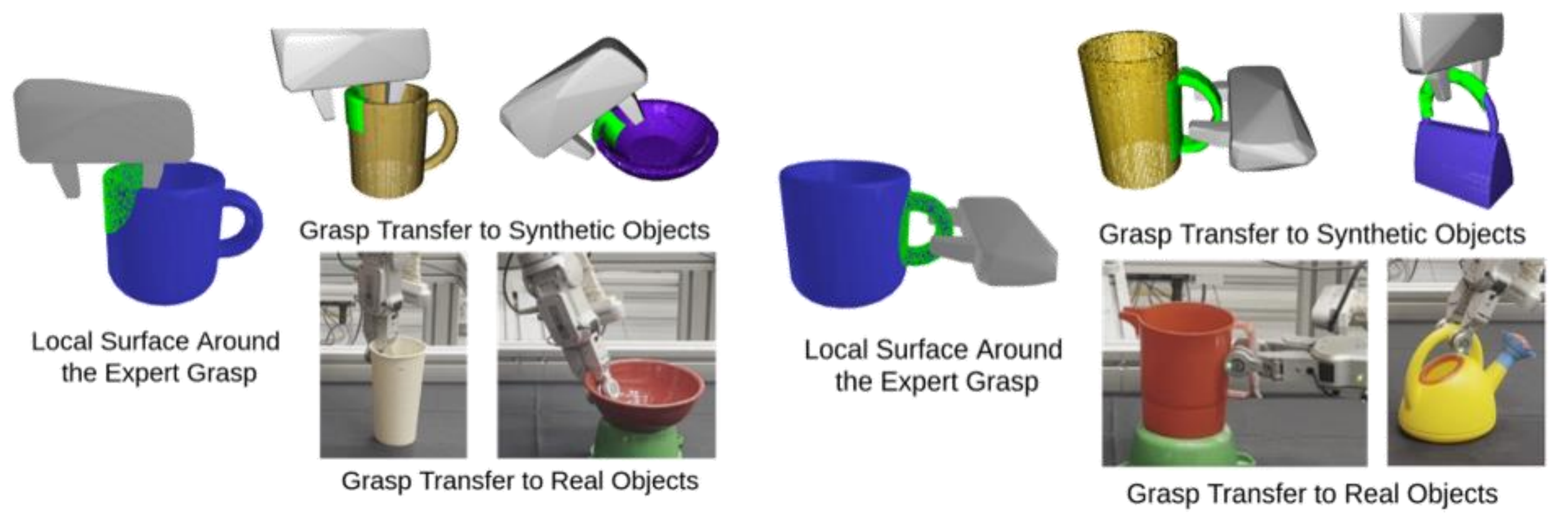
Data Efficient Representation Learning with 3D Data - Grasp Transfer with Local Surface Models

Grasp Transfer based on Self-Aligning Implicit Representations of Local Surfaces
Ahmet Tekden, Marc Peter Deisenroth, Yasemin Bekiroglu, RAL 2023, ICRA 2024.

Objects share similar parts where similar grasps can be applied.



- Objects we interact with and manipulate often **share similar parts**, such as handles and rims, where **similar grasps** can be applied.
- In this work, we study **transferring grasp experience** or demonstration to novel objects that **share shape similarities** with objects a robot has previously experienced.

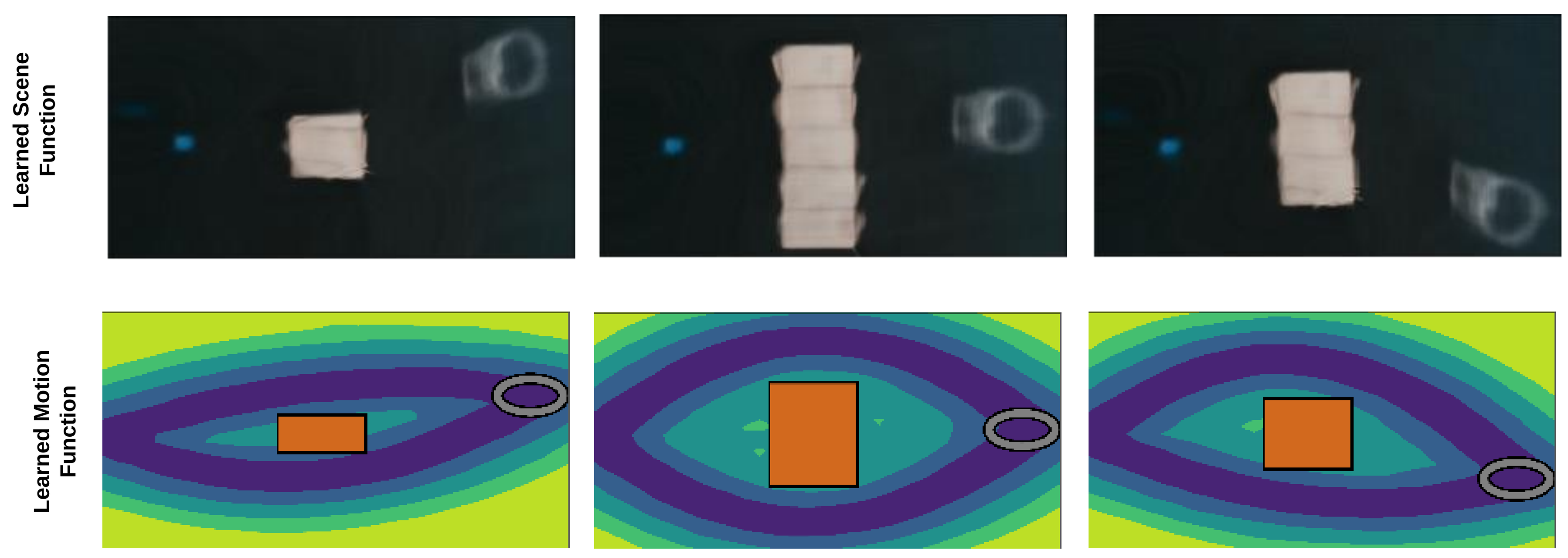


We **model local surfaces** to **transfer grasps** between objects that **share a geometrically similar part** such as bags and bowls.

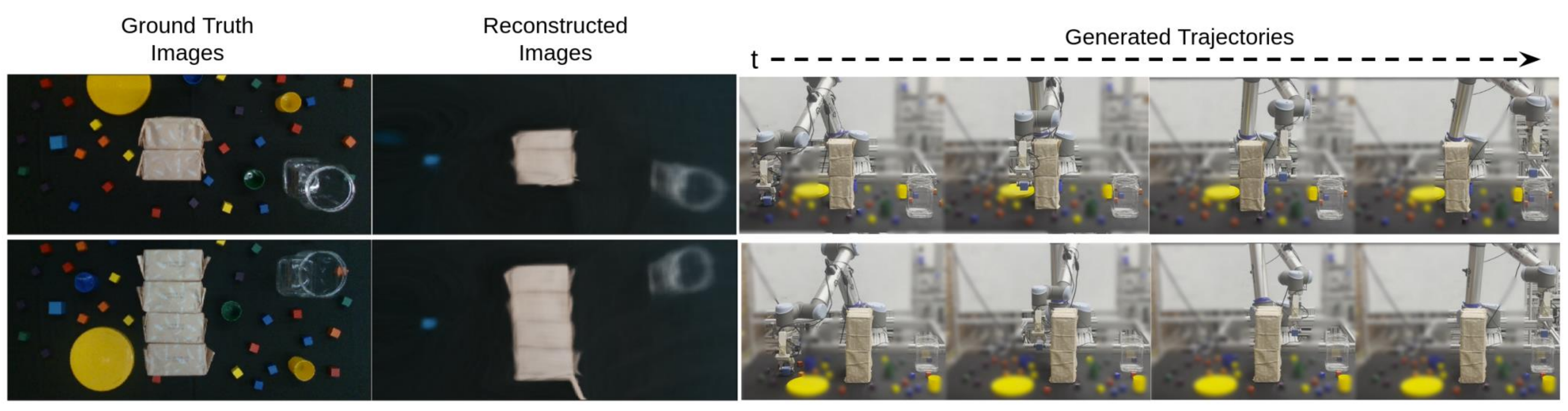
Data Efficient Representation Learning for Motion Generation - Joint Modeling of Motion and Scene Representations

Neural Field Movement Primitives for Joint Modelling of Scenes and Motions
Ahmet Tekden, Marc Peter Deisenroth, Yasemin Bekiroglu, IROS 2023

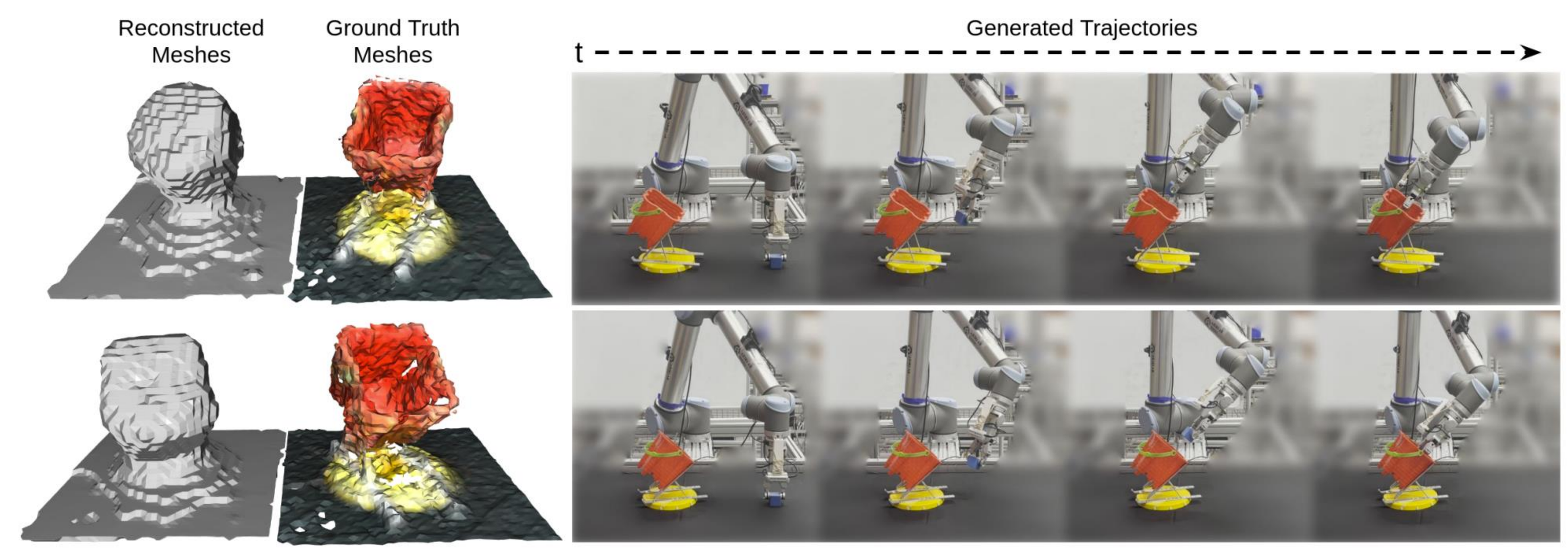
- Task Parameters - **Challenging to obtain** to sufficiently describe the scene.
- Raw Images - **Require high number of expert demonstrations** that are densely sampled with respect to task parameters.



Proposed Method - **Jointly modelling** scenes and motions in a generative way with **neural fields** as **smooth functions of shared embeddings**.



Modeling multi-valued trajecories via **implicit functions of end-effector trajectories** as motion representation, and **RGB images,** as function of pixels locations, as scene representation. The method is **robust to distractor objects** introduced at inference time.



Modeling **Joint angle trajectories,** as function of time, as motion representation, and **3D shapes,** via signed distance functions, as scene representation. The method is capable of utilizing **surface-based 3D representations** which do not have a structured rasterized format

Data Efficient Learning for Reactive and Composable Motion Generation - Dynamical Systems as Smooth Energy Functions

We propose an energy-based dynamical system (DS) representation:

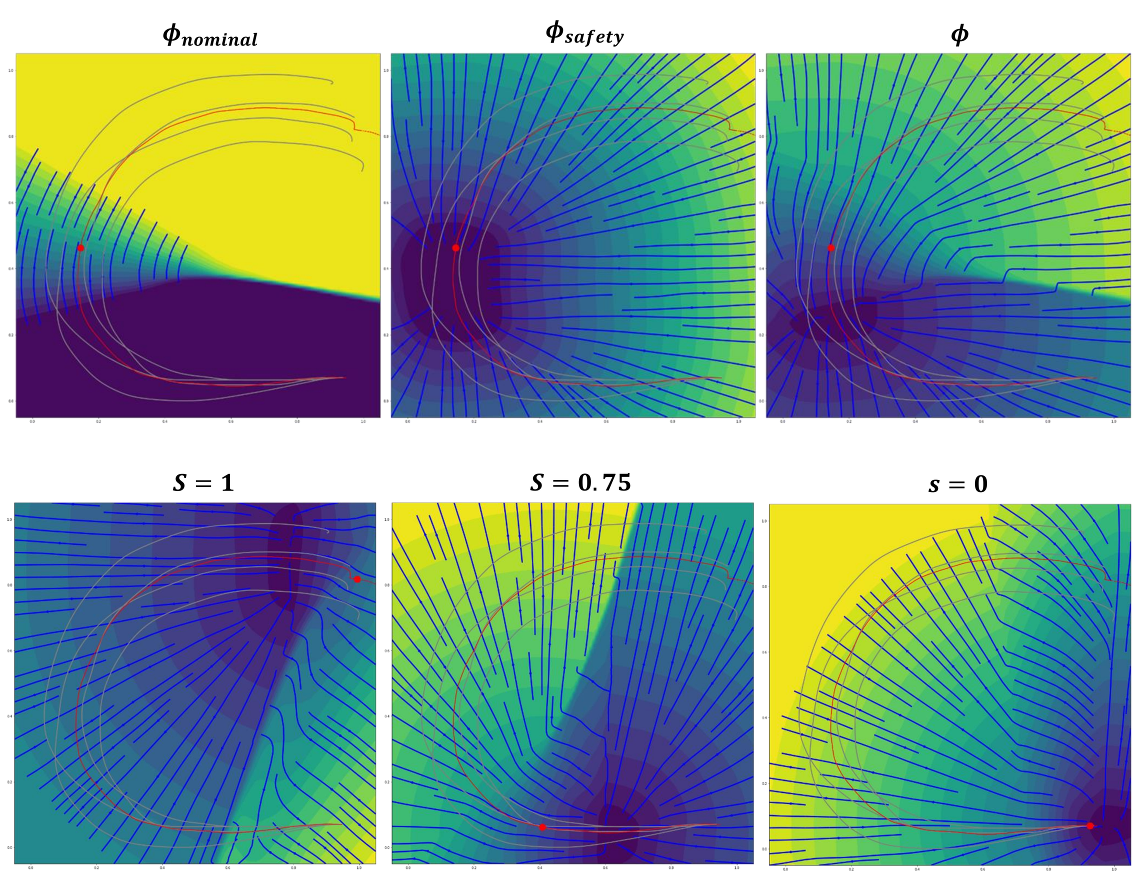
$$s_{t-1}: s_{t+1} = \phi(x_{t-1}: x_{t+1} | s_t), \nabla_x \phi(x|s) = \dot{x}$$

where ϕ models the local potential energy function based on $\phi_{nominal}$ for representing the nominal behaviour and ϕ_{safety} for ensuring safety and stability. Our main contributions are:

1) We model the behaviour as an Autonomous (time-invariant) DS through a close-loop canonical system (with time reparametrization) s which is estimated through $\phi_{nominal}$.

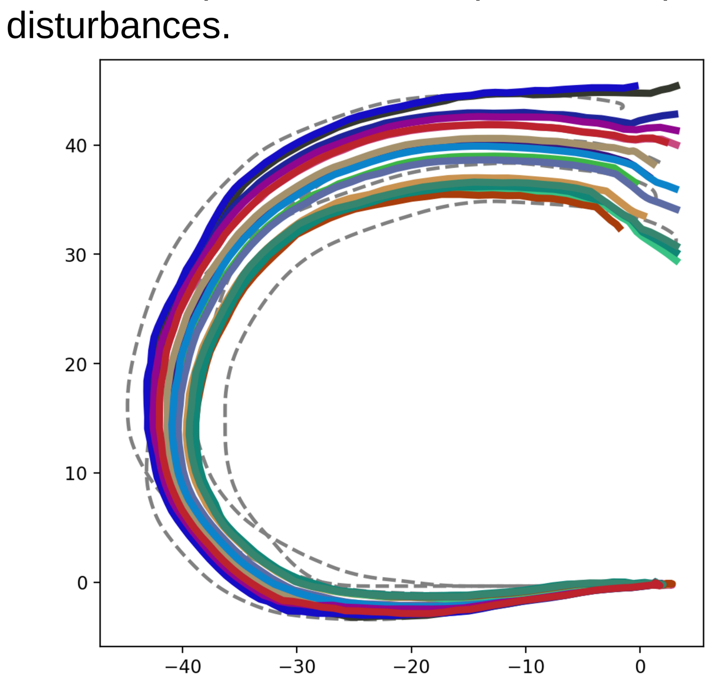
2) Complex trajectories, e.g. with intersections in state-space, can be represented as a first order dynamical system.

3) The experiments show that the system is robust to disturbances.



Training and nominal (estimated) trajectories are shown with gray and red lines, respectively. The red circle indicates the robot's position at a specific s value.

The proposed representation of DS is smooth and stable, providing accurate trajectory generation that follows the nominal behavior even in the presence of temporal and spatial disturbances.



Trajectories generated from different initial positions. Gray dashed lines indicate training trajectories.

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