

論文の内容の要旨

論文題目 Robotic Manipulation Teaching System Based on
Object-pair Mutual Function Knowledge with a Few Visual Demonstrations
(少数の視覚演示と対物体相互機能知識に基づくロボット
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Robot manipulation teaching system is a crucial intermedium when general users want to teach robots new manipulation knowledge without the help of experts. However, given robots a limited amount of demonstrations and require them to generalize the learned knowledge to new instances is a difficult problem. Towards reducing user effort in robot teaching, this thesis contributes a robot manipulation teaching system that enables robots to extract meaningful knowledge from a few visual demonstrations and leverage the learned knowledge in handling complex variations.

The thesis first defines an object-pair mutual function knowledge model that enables robots to generalize the elements of the knowledge model to new instances. The main difference between the proposed knowledge model and the previous knowledge models is that the proposed knowledge model adopts the object functional part to determine whether a new instance can be used to achieve a known function, while the previous knowledge models have difficulty in handling new instances because they require prior knowledge for the instances.

Next, the thesis presents an on-site teaching approach that can extract knowledge from human teaching. The whole process has three main steps including handheld object extraction, object functional part extraction, and object motion trajectory extraction. Each step is transparent to the demonstrator because the demonstrator can see the extraction outcomes. Unlike previous methods that only record a series of robot end-effector positions or human hand positions for trajectory learning. The proposed method applied a hand keypoint detector to figure out the interaction between human hand and object, and thus enables the robot to extract more visual variables for learning.

The virtual teaching tool is supplementary to the on-site teaching approach because in some situations using only hand gestures for teaching is difficult. The virtual teaching tool also allows users to teach robots through 3D CAD models.

This thesis also proposed a data augmentation framework and an object-pair mutual function knowledge acquisition network. The data augmentation framework is able to enrich the demonstration samples with different position changes. Since the demonstration samples given by users are limited, the learning algorithm is difficult to notice how position changes affect the output results. By given more augmented demonstrations with different relative object positions, the network has learned to choose proper pose trajectories to handle different situations. The relationship between the number of augmented samples and network training time is also estimated.

In the task reproduction phases, this thesis proposed a framework that has three main components: the semantic instance segmentation component receives the user command as inputs and detect target objects in the environment through the RGB images. The point cloud processor receives the image masks given by the semantic instance segmentation component and converts the pixel within the masks to point clouds, according to the user input function, this component attaches the activation signals to the corresponding objects. The trajectory and grasping pose generation component takes the point cloud as inputs and outputs motion trajectory and grasping pose for the desired function to guide robots to perform tasks. Comparing different trajectory generation methods, this thesis shows that the object function knowledge-based method outperforms the instance-based method in handling new instances for known manipulation tasks.

Finally, this thesis shows how to integrate the robot teaching system to a real robot platform. Through the experiment, this thesis shows how the proposed system enables the robot to gain new knowledge to carry out daily tasks. The experiment also shows the robot has successfully handled the position variation, the intra-category shape variation, and the initial state variation after learning from a few human teaching.

By enabling robots to generalize the learned manipulation knowledge from a few human demonstrations, this thesis contributes towards an effective robot manipulation teaching system that not only allows transparent teaching but also is able to handle different kinds of variations through a limited amount of demonstrations.