Published in Proceedings of DRG-Days 2017 (http://dgr2017.informatik.uni-bremen.de/wp-content/uploads/2017/11/Proceedings-DGR-Days-2017.pdf)

Citation: Kerzel, Matthias and Wermter, Stefan. Learning of Neurobotic Visuomotor Abilities based on Interactions with the Environment. Proceedings of the DGR Days 2017, pages 14--15 - Nov 2017.

Learning of Neurobotic Visuomotor Abilities based on Interactions with the Environment

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Abstract— **Robotic visuomotor abilities, like grasping, can either be realized through conventional means of independent modules for subtasks like object localization, grasp planning, and inverse kinematics. These modules, however, rely on the availability of accurate robot and environment models. An alternative is to acquire visuomotor abilities through end-to-end machine learning. While deep neural networks have proved successful in many areas, they depend on large amounts of annotated training data or long periods of trial-and-error learning.**

To overcome this issue, developmental robotics leverages principles of incremental learning in biological agents. Increasingly complex visuomotor abilities are learned through mostly autonomous interaction with the environment. Following this paradigm, we present current research on acquiring visuomotor skills with a humanoid robot through self-learning and minimal human assistance. The robot engages in a learning cycle where it repeatedly manipulates an object to gather training samples that link its actions (joint configurations) to states of the environment (images from the robot's perspective). Human assistance is only requested if errors occur during this phase, e.g., the training object is accidentally dropped out of reach. Based on these training samples, supervised end-to-end learning of visuomotor skills is realized with a deep convolutional neural architecture. The results show that the approach generalizes well to novel objects that were not included in learning. To enable this research, we developed NICO, the Neuro Inspired COmpanion, a humanoid research platform for embodied neurobotic models and human-robot interaction.

Preferred type of presentation: Oral

I. Motivation and Problem Definition

Grasping is an important visuomotor ability that enables object manipulation, haptic perception and general interaction with the environment. Conventional approaches rely on accurate robot and environment models that realize different subtasks like object localization, grasp planning, and inverse kinematics, e.g., [1]. These models, however, are not always available. If a robot is modified, uses a novel tool or is employed in an unknown environment, it would be preferable if it could learn to adapt to the new challenge.

This adaptation can be achieved with approaches that acquire visuomotor abilities through end-to-end machine learning. Deep neural networks have proved successful in many areas, but they rely on large amounts of training data. This data can be created by human annotators, or it can be generated through trial-and-error learning. Both of these options are time-consuming. Therefore, we employ methods from developmental robotics [2], where increasingly complex interactions with the environment facilitate learning of visuomotor abilities.

II. Related Work

Recent advances in deep neural architectures allow end-to-end learning of visuomotor abilities. A robot can acquire these abilities through trial-and-error interaction with the environment. These approaches have proven successful in both discrete [3] and continuous [4] virtual environments. However, these approaches require a large number of training iterations resulting in hundreds of hours of training ([5]), thus making them infeasible in many real environments due to time constraints or possible damage to the robot.

To overcome this problem, learning can be transformed into simpler tasks that can then be learned in a supervised way. A neural network can, for instance, be trained with samples that are fully annotated by exploiting the forward kinematics of the robot ([6]).

III. Own Approach and Contribution

The presented approach follows the developmental robotics paradigm, where increasingly sophisticated cognitive and sensorimotor abilities are developed through learning. In our approach, a robot learns to grasp by using its motoric and sensory capabilities to interact with the environment. We exploit the fact that the same joint configuration used to place an object can also be used to grasp an object. During training, the robot performs a self-learning cycle in which it autonomously places and re-grasps an object at random positions on a table. Through this repeated interaction, it gathers training samples that link the robot's actions to its perception of the environment. In doing so, the robot generates fully annotated samples that are suitable for end-to-end learning of a deep neural architecture [7]. No robot or environment model is needed for this process. Also, human assistance is required only to initialize the training or to assist in the case of errors. If for instance, the training object is accidentally dropped out of reach, the robot realizes it's failed attempt to re-grasp the object and actively requests help.

The results show that the approach generalizes well to novel objects that were not included in learning. Furthermore, the approach can be integrated into a dialogue system, that enables non-expert users to train a robot's visuomotor abilities ([8])

As a robotic platform for research on embodied neurobotic models and human-robot interaction, we present NICO ([9]),

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the Neuro Inspired COmpanion. NICO is an adaptable humanoid that features visual, auditory and haptic perception, a human-like range of movement for object manipulation and a facial display of stylized emotions during human-robot interaction.

ACKNOWLEDGMENT

The authors gratefully acknowledge partial support from the German Research Foundation DFG under project CML (TRR 169) and the Hamburg Landesforschungsförderungsprojekt CROSS.

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