First Steps in Building a Framework for Learning by Experimentation

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I. Introduction

Dynamic environments and changing tasks still pose a major challenge for robotic learning in real-world domains. In order to intelligently adapt its task strategies, the agent needs capabilities to understand its environment and the effects of its actions. In order to approach this challenge within an open-ended learning loop, the XPERO project (http://www.xpero.org) explores the paradigm of *learning by experimentation* to increase the robot's conceptual world knowledge autonomously. In this setting, tasks which are selected by an action-selection mechanism are interrupted by a learning loop in those cases where the robot identifies learning as necessary for solving a task or for explaining observations.

II. The Proposed Framework

We propose a framework for designing experiments to be executed by a robotic learner which implements the paradigm of learning by experimentation. This framework integrates a *stimulation* and *experimentation* components which interact by using available knowledge about the environment. The *stimulation* component works under the assumption that the knowledge available to the robot can *predict* and *explain* any observation derived from the effect of the robot actions on the environment. When a prediction fails (this is, a significant divergence between expectation and observation exists), experimentation is triggered. A component called *educated guessing* selects a feature subset which should include the features relevant for the new or revised theory. The idea is to identify the physical quantities, which may have contributed to the observed, surprising phenomenon and might be part of a theory that explains it. The *experimentation* component, which is the focus of our framework, receives a surprise signal from the *stimulation* module whenever an observation diverges from the prediction. Using information about the initial state of the environment as perceived by the robot, the action sequences, the prediction rule which failed, and the parameter values which generated the surprise, it analyzes the observed event and the surprise obtained, designs and executes sequences of robot actions (*experiments*) in order to collect target-oriented data that afford learning new concepts.

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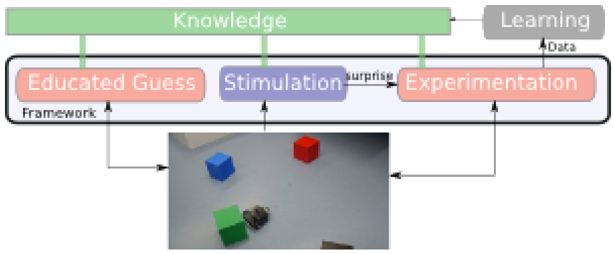

Fig. 1: The framework for design of experiments

The output of the experimentation module is thus intended to provide a machine learning algorithm with data in a format appropriate for learning conceptual knowledge.

III. Preliminary Results

We developed a software implementation of our framework based on the ideas presented in Section II. This consists of several components: *stimulation, educated guessing*, and *experimentation* modules implement the main idea, while a *feature extraction* module prepares data for a learning algorithm that obtains new knowledge.

The software was used within the showcase scenario of XPERO project: a robot is in an environment with several objects whose properties are partially unknown. Starting with the hypothesis that all objects are non-movable, with our approach, the robot was able to use this knowledge to predict the outcome of its actions and recognize when a prediction failure occurs (the displacement of an object). This event triggers experimentation that enables the selection of a sequence of actions to interact with objects (pushing), with the objective of collecting meaningful data that will be used to improve knowledge and gain insights.

As shown in [1], the data collected by our framework successfully enabled the learning of the concept of *movability* of objects using the machine learning tool HYPER, a tool for Inductive Logic Programming (ILP) capable of predicate invention.

References

[1] G. Leban, J. Zabkar, and I. Bratko, "An experiment in robot discovery with ILP," in *Proceedings of the 18th. International Conference on Inductive Logic Programming*, 2008.