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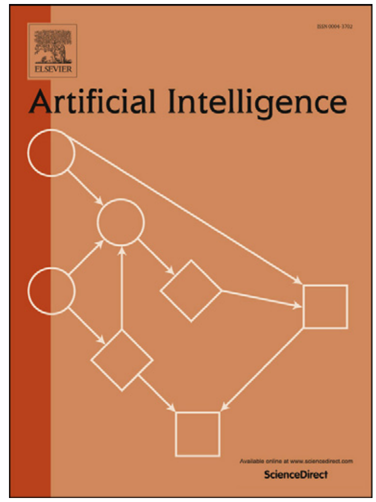

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Envisioning the Qualitative Effects of Robot Manipulation Actions using Simulation-based Projections

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Abstract

Autonomous robots that are to perform complex everyday tasks such as making pancakes have to understand how the effects of an action depend on the way the action is executed. Within Artificial Intelligence, classical planning reasons about whether actions are executable, but makes the assumption that the actions will succeed (with some probability). In this work, we have designed, implemented, and analyzed a framework that allows us to *envision* the physical effects of robot manipulation actions. We consider *envisioning* to be a qualitative reasoning method that reasons about actions and their effects based on simulation-based projections. Thereby it allows a robot to infer *what could happen* when it performs a task in a certain way. This is achieved by translating a qualitative physics problem into a parameterized simulation problem; performing a detailed physics-based simulation of a robot plan; logging the state evolution into appropriate data structures; and then translating these sub-symbolic data structures into interval-based first-order symbolic, qualitative representations, called timelines. The result of the envisioning is a set of detailed narratives represented by timelines which are then used to infer answers to qualitative reasoning problems. By envisioning the outcome of actions before committing to them, a robot is able to reason about physical phenomena and can therefore prevent itself from ending up in unwanted situations. Using this approach, robots can perform manipulation tasks more efficiently, robustly, and flexibly, and they can even successfully accomplish previously unknown variations of tasks.

Keywords: Envisioning, Simulation-based Projections, Naive Physics, Everyday Robot Manipulation

1. Introduction

In recent years, we have seen substantial progress towards personal robot assistants which are able to perform everyday household chores such as cleaning a room[1] or preparing a meal (Beetz et al., 2011). However, designing and building robots that can autonomously perform an open-ended set of manipulation tasks in human environments remains an unsolved problem and poses many challenges to the field (Kemp et al., 2007). One of the challenges is enabling robots to learn how to perform novel tasks from natural instructions, for example interpreting natural language instructions (Tenorth et al., 2010b) or analyzing observations of a human performing the task (Beetz et al., 2010b). Based on such information, a robot has to understand the nature of the task, that is, it has to reason about *how the physical effects of a manipulation action depend on the way the action is executed*. In particular, to perform the task itself, the robot has to understand how its own manipulation actions produce physical effects. For example, how does the pose of the robot's end-effector affect the outcome of a pouring action when a liquid is poured from one container to another.

Within Artificial Intelligence (AI), the problem of reasoning about actions is often considered in the area of classical planning. In contrast to the question of *how the effects of an action depend on how it is executed?*, the question that classical planning typically considers is *what effects are caused by an action?* However, in the context of robotics, the problem has to be approached from a different direction, because *how* an action is executed has a major influence on its consequences. Furthermore, classical planning approaches are inadequate for everyday manipulation for two reasons: open-ended tasks makes classical planning intractable; and robot control programs cannot be adequately

[1]`http://personalrobotics.stanford.edu`