Acquiring Observation Models Through Reverse Plan Monitoring

Sonia Chernova, Elisabeth Crawford, and Manuela Veloso

Computer Science Department, Carnegie Mellon University,
Pittsburgh PA 15213, USA

Abstract. We present a general-purpose framework for updating a robot's observation model within the context of planning and execution. Traditional plan execution relies on monitoring plan step transitions through accurate state observations obtained from sensory data. In order to gather meaningful state data from sensors, tedious and time-consuming calibration methods are often required. To address this problem we introduce *Reverse Monitoring*, a process of learning an observation model through the use of plans composed of scripted actions. The automatically acquired observation models allow the robot to adapt to changes in the environment and robustly execute arbitrary plans. We have fully implemented the method in our AIBO robots, and our empirical results demonstrate its effectiveness.

1 Introduction

In the traditional planning and execution scenario (e.g., [7]), a plan consists of a sequence of actions defined as a set of preconditions and a set of effects. When executing a plan action, the robot first checks if the preconditions of the step are satisfied in the current state. For instance, before attempting to execute the plan action "open door A," the robot needs to be able to detect the action precondition "in front of door A." Once the action is executed the robot can then verify the effect of the action ("door A open") before deciding if the preconditions for the next action are met. These preconditions and effects are perceived through sensory data. Often the perceptions that the robot needs to make are complicated and thus the sensors must be very accurately calibrated.

In order to gather meaningful data from sensors, tedious and time-consuming calibration methods are often required. Calibration often needs to be performed for each sensor individually, and, in some cases, changes to the environment can make recalibration necessary. Traditionally, calibration processes are executed manually by a human expert until the desired behavior is achieved. We believe that many calibration tasks can be automated to a large degree, greatly reducing the level of human involvement without sacrificing the quality of the results. We propose a method to approach this problem that combines elements of calibration and plan execution.

An integrated robot planning and execution framework requires accurate state detection. However, as all actions have expected effects associated with

C. Bento, A. Cardoso, and G. Dias (Eds.): EPIA 2005, LNAI 3808, pp. 410–421, 2005.

them, we can also consider blindly executing a sequence of plan steps and then letting the robot associate the perceived state with the expected state. In this paper, we contribute a novel way of approaching plan execution - we *reverse* the perception role. Instead of expecting the robot to be able to accurately perceive the preconditions of actions, our approach, Reverse Monitoring, assumes that the robot knows the effects of the actions, can detect triggers of actions at a reduced level of detail, and can then associate its full perceived state with the effect of the actions. As we show in this paper, the robot is capable of refining its perception models to a higher level of detail through the execution of scripted plans. In this way, robots can autonomously acquire the accurate models they need to execute plans that require detailed sensing.

We demonstrate the effectiveness of our approach using the vision calibration system developed for the Sony AIBO robot. A typical vision calibration sequence on an AIBO robot requires a human to place the robot at various points in the domain to collect images of landmarks for calibration. The user must then hand-label each of the pixels in the images to classify it into one of the discrete color classes. Our proposed method allows the robot to collect and classify images with very little human assistance. This is accomplished by providing the robot with a plan that allows it to navigate by relying on sensing data in a reduced dimensionality space. As the robot proceeds with the plan and gathers information, its observation model is enriched, allowing the robot to sense in higher dimensions. When the execution of the plan is completed, the robot's sensors have been fully calibrated and it is then able to execute plans that require more detailed sensing.

We are not aware of any previous work combining the elements of plan execution and observation model refinement in a formal framework. Planning literature dealing with robots in the real world generally assumes a working sensor model and focuses mainly on issues of noisy sensors and partially observed states [4,5,7]. A large body of work relating to autonomous sensor calibration also exists, however these methods tend to focus on domain-specific or sensor-specific solutions [6,9,11,12,14]. We propose a general-purpose framework for updating a robot's observation model in the context of planning that is independent of the particular system or domain being used. The following sections present our approach in greater detail and present results demonstrating its effectiveness when applied to an existing robotic system.

2 Observation Models from Reverse Monitoring

2.1 Monitoring

A plan is a series of actions to be carried out in sequence. In classical planning actions have no duration; their effects are instantaneous and therefore the termination point of each action is clear. More realistic planning domains require the use of actions with durations. Durative actions typically represent a period of time where certain conditions are true at the beginning and at the end of the