

## 7. Actions and Events in Interval Temporal Logic

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### 7.1. Introduction

Representing and reasoning about the dynamic aspects of the world — primarily about actions and events — is a problem of interest to many different disciplines. In Artificial Intelligence (AI), we are interested in such problems for a number of reasons — in particular, to model the reasoning of intelligent agents as they plan to act in the world and to reason about causal effects in the world. More specifically, a general representation of actions and events has to support the following somewhat overlapping tasks:

- *Prediction*: Given a description of a scenario, including actions and events, what will (or is most likely to) happen?
- *Planning*: Given an initial description of the world and a desired goal, find a course of action that will (or is most likely to) achieve that goal.
- *Explanation*: Given a set of observations about the world, find the best explanation of the data. When the observations are another agent's actions and the explanation desired is the agent's plan, the problem is called *plan recognition*.

Our claim in this chapter is that in order to adequately represent actions and events, one needs an explicit temporal logic, and that approaches with weaker temporal models, such as state spaces (for example, STRIPS-based approaches) and the situation calculus, either cannot handle the problems or require such dramatic extensions that one in effect has grafted an explicit temporal logic onto the earlier formalism. Furthermore, if one of these formalisms is extended in this way, the temporal logic part will dominate and the original formalism plays little role in the solution. We will primarily

defend this position by proposing a specific temporal representation and showing that it can handle a wide range of situations that are often problematic for other formalisms. In particular, here are some properties of actions and events that we feel are essential to any general representation:

- Actions and events take time. During this time, they may have a rich structure. For instance, the event of driving my car to work involves a wide range of different actions, states of the world, and other complications, yet the activity over that stretch of time is appropriately described as a single event.
- The relationship between actions and events and their effects is complex. Some effects become true at the end of the event and remain true for some time after the event. For example, when I put a book on the table, this has the effect that the book is on the table for at least a short time after the action is completed. Other effects only hold while the event is in progress — for example, holding an elevator open by pressing the “open door” button. Other effects might start after the beginning of the event and end before it does, such as my being on a bridge while driving to work. This is an effect of the action even though it is not true at the end of it. Finally, it may be the case that the effects of actions are wholly independent of the action once the action is performed, as in a rock rolling down a hill after I nudge it out of place.
- External changes in the world may occur no matter what actions an agent plans to do and may interact with the planned actions. Possible external events should be an important factor when reasoning about what effects an action might have. Certain goals can be accomplished only by depending on external events, whether they are a result of natural forces (sailing, for example, needs wind) or the actions of other agents (needed cargo arrives when a vehicle arrives).
- Actions and events may interact in complex ways when they overlap or occur simultaneously. In some cases, they interfere with certain effects that would arise if the events were done in isolation. In other cases, the effects may be additive. And in still other cases, the effect of performing the two actions may be completely different from the effects of each in isolation.
- Knowledge of the world is necessarily incomplete and unpredictable in detail. Thus, reasoning about actions and events can be done only on the basis of certain assumptions. No plan is foolproof, and it is important that a formalism makes the necessary assumptions explicit so that they can be considered in evaluating plans.

Our aim is to develop a general representation of actions and events that supports a wide range of reasoning tasks, including planning, explanation,