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## INTELLIGENT AGENTS

*In which we discuss what an intelligent agent does, how it is related to its environment, how it is evaluated, and how we might go about building one.*

### 2.1 INTRODUCTION

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An **agent** is anything that can be viewed as **perceiving** its environment through **sensors** and **acting** upon that environment through **effectors**. A human agent has eyes, ears, and other organs for sensors, and hands, legs, mouth, and other body parts for effectors. A robotic agent substitutes cameras and infrared range finders for the sensors and various motors for the effectors. A software agent has encoded bit strings as its percepts and actions. A generic agent is diagrammed in Figure 2.1.

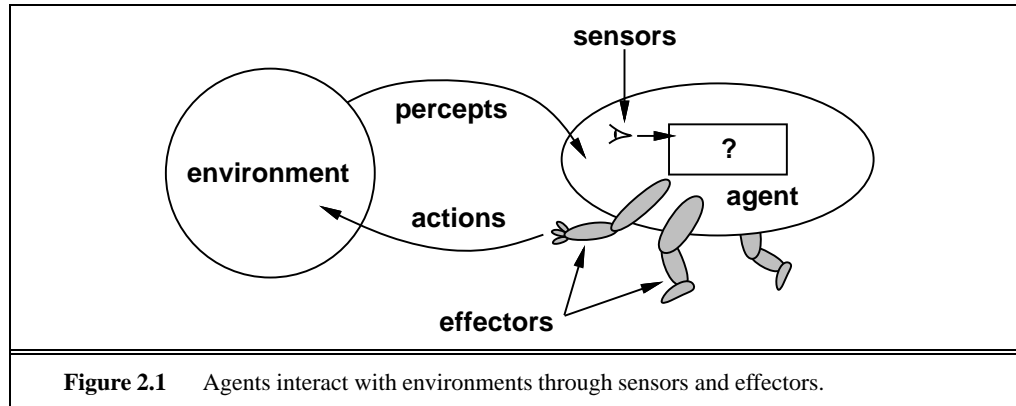
Our aim in this book is to design agents that do a good job of acting on their environment. First, we will be a little more precise about what we mean by a good job. Then we will talk about different designs for successful agents—filling in the question mark in Figure 2.1. We discuss some of the general principles used in the design of agents throughout the book, chief among which is the principle that agents should *know* things. Finally, we show how to couple an agent to an environment and describe several kinds of environments.

### 2.2 HOW AGENTS SHOULD ACT

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#### RATIONAL AGENT

A **rational agent** is one that does the right thing. Obviously, this is better than doing the wrong thing, but what does it mean? As a first approximation, we will say that the right action is the one that will cause the agent to be most successful. That leaves us with the problem of deciding *how* and *when* to evaluate the agent's success.



PERFORMANCE  
MEASURE

We use the term **performance measure** for the *how*—the criteria that determine how successful an agent is. Obviously, there is not one fixed measure suitable for all agents. We could ask the agent for a subjective opinion of how happy it is with its own performance, but some agents would be unable to answer, and others would delude themselves. (Human agents in particular are notorious for “sour grapes”—saying they did not really want something after they are unsuccessful at getting it.) Therefore, we will insist on an objective performance measure imposed by some authority. In other words, we as outside observers establish a standard of what it means to be successful in an environment and use it to measure the performance of agents.

As an example, consider the case of an agent that is supposed to vacuum a dirty floor. A plausible performance measure would be the amount of dirt cleaned up in a single eight-hour shift. A more sophisticated performance measure would factor in the amount of electricity consumed and the amount of noise generated as well. A third performance measure might give highest marks to an agent that not only cleans the floor quietly and efficiently, but also finds time to go windsurfing at the weekend.<sup>1</sup>

The *when* of evaluating performance is also important. If we measured how much dirt the agent had cleaned up in the first hour of the day, we would be rewarding those agents that start fast (even if they do little or no work later on), and punishing those that work consistently. Thus, we want to measure performance over the long run, be it an eight-hour shift or a lifetime.

OMNISCIENCE

We need to be careful to distinguish between rationality and **omniscience**. An omniscient agent knows the *actual* outcome of its actions, and can act accordingly; but omniscience is impossible in reality. Consider the following example: I am walking along the Champs Élysées one day and I see an old friend across the street. There is no traffic nearby and I’m not otherwise engaged, so, being rational, I start to cross the street. Meanwhile, at 33,000 feet, a cargo door falls off a passing airliner,<sup>2</sup> and before I make it to the other side of the street I am flattened. Was I irrational to cross the street? It is unlikely that my obituary would read “Idiot attempts to cross

<sup>1</sup> There is a danger here for those who establish performance measures: you often get what you ask for. That is, if you measure success by the amount of dirt cleaned up, then some clever agent is bound to bring in a load of dirt each morning, quickly clean it up, and get a good performance score. What you really want to measure is how clean the floor is, but determining that is more difficult than just weighing the dirt cleaned up.

<sup>2</sup> See N. Henderson, “New door latches urged for Boeing 747 jumbo jets,” *Washington Post*, 8/24/89.

street.” Rather, this points out that rationality is concerned with *expected* success *given what has been perceived*. Crossing the street was rational because most of the time the crossing would be successful, and there was no way I could have foreseen the falling door. Note that another agent that was equipped with radar for detecting falling doors or a steel cage strong enough to repel them would be more successful, but it would not be any more rational.

In other words, we cannot blame an agent for failing to take into account something it could not perceive, or for failing to take an action (such as repelling the cargo door) that it is incapable of taking. But relaxing the requirement of perfection is not just a question of being fair to agents. The point is that if we specify that an intelligent agent should always do what is *actually* the right thing, it will be impossible to design an agent to fulfill this specification—unless we improve the performance of crystal balls.

In summary, what is rational at any given time depends on four things:

- The performance measure that defines degree of success.
- Everything that the agent has perceived so far. We will call this complete perceptual history the **percept sequence**.
- What the agent knows about the environment.
- The actions that the agent can perform.

PERCEPT SEQUENCE

IDEAL RATIONAL  
AGENT



This leads to a definition of an **ideal rational agent**: *For each possible percept sequence, an ideal rational agent should do whatever action is expected to maximize its performance measure, on the basis of the evidence provided by the percept sequence and whatever built-in knowledge the agent has.*

We need to look carefully at this definition. At first glance, it might appear to allow an agent to indulge in some decidedly underintelligent activities. For example, if an agent does not look both ways before crossing a busy road, then its percept sequence will not tell it that there is a large truck approaching at high speed. The definition seems to say that it would be OK for it to cross the road. In fact, this interpretation is wrong on two counts. First, it would not be rational to cross the road: the risk of crossing without looking is too great. Second, an ideal rational agent would have chosen the “looking” action before stepping into the street, because looking helps maximize the expected performance. Doing actions *in order to obtain useful information* is an important part of rationality and is covered in depth in Chapter 16.

The notion of an agent is meant to be a tool for analyzing systems, not an absolute characterization that divides the world into agents and non-agents. Consider a clock. It can be thought of as just an inanimate object, or it can be thought of as a simple agent. As an agent, most clocks always do the right action: moving their hands (or displaying digits) in the proper fashion. Clocks are a kind of degenerate agent in that their percept sequence is empty; no matter what happens outside, the clock’s action should be unaffected.

Well, this is not quite true. If the clock and its owner take a trip from California to Australia, the right thing for the clock to do would be to turn itself back six hours. We do not get upset at our clocks for failing to do this because we realize that they are acting rationally, given their lack of perceptual equipment.<sup>3</sup>

<sup>3</sup> One of the authors still gets a small thrill when his computer successfully resets itself at daylight savings time.