Chapter 4
Programming Rational Agents in GOAL

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Abstract The agent programming language GOAL is a high-level programming language to program rational agents that derive their choice of action from their beliefs and goals. The language provides the basic building blocks to design and implement rational agents by means of a set of programming constructs. These programming constructs allow and facilitate the manipulation of an agent’s beliefs and goals and to structure its decision-making. GOAL agents are called rational because they satisfy a number of basic rationality constraints and because they decide to perform actions to further their goals based upon a reasoning scheme derived from practical reasoning. The programming concepts of belief and goal incorporated into GOAL provide the basis for this form of reasoning and are similar to their common sense counterparts used everyday to explain the actions that we perform. In addition, GOAL provides the means for agents to focus their attention on specific goals and to communicate at the knowledge level. This provides an intuitive basis for writing high-level agent programs. At the same time these concepts and programming constructs have a well-defined, formal semantics. The formal semantics provides the basis for defining a verification framework for GOAL for verifying and reasoning about GOAL agents which is similar to some of the well-known agent logics introduced in the literature.

4.1 Motivation

The concept of a goal lies at the basis of our understanding of why we perform actions. It is common sense to explain the things we do in terms of beliefs and goals. I started writing this chapter with the goal of explaining the programming language GOAL. The reasons for performing actions are derived from our moti-

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vations and the notion of \textit{rational behaviour} is typically explained in terms of actions that are produced in order to further our goals \cite{5, 14, 16}. A researcher that has a goal to have finished a book chapter but is going on a holiday instead is not considered to behave rationally because holidays do not further the goal of writing a book chapter.

The idea to use common sense notions to build programs can be traced back to the beginnings of Artificial Intelligence. Shoham, who was one of the first to propose a new programming paradigm that he called \textit{agent-oriented programming}, cites McCarthy about the usefulness of ascribing such notions to machines \cite{29, 39}. One of the first papers on Artificial Intelligence, also written by McCarthy, is called \textit{Programs with Common Sense} \cite{28}. It has been realized that in order to have machines compute with such notions it is imperative to precisely specify their meaning \cite{39}. To this end, various logical accounts have been proposed, mainly using modal logic, to clarify the core common sense meaning of these notions \cite{10, 25, 34}. These accounts have aimed to precisely capture the essence of a conceptual scheme based on common sense that may also be useful and applicable in specifying rational agent programs. The first challenge thus is to provide a well-defined semantics for the notions of belief, goal and action which can also provide a computational interpretation of these notions useful for programming agents.

One of the differences between our approach and earlier attempts to put common sense concepts to good use in Artificial Intelligence is that we take a definite \textit{engineering stance} (contrast \cite{28} and \cite{39}). The concepts are used to introduce a new agent programming language that provides useful programming constructs to develop agent programs. The second challenge is to provide agent programming language that is practical, transparent, and useful. It must be practical in the sense of being easy to use, transparent in the sense of being easy to understand, and useful in the sense of providing a language that can solve real problems.

\subsection*{4.1.1 The GOAL Agent Programming Language}

The agent programming language \textit{GOAL} that we will introduce and discuss meets both of the challenges identified above \cite{3, 22}. The distinguishing feature of the language \textit{GOAL} is its notion of \textit{declarative goals} and the way agents derive their choice of actions from such goals.\footnote{\textit{GOAL} is an acronym for \textit{Goal-Oriented Agent Language}.} The beliefs and goals of a \textit{GOAL} agent are called its \textit{mental state}. Various constraints are placed on the mental state of an agent, which roughly correspond to constraints on their common sense counterparts. On top of the mental attitudes a \textit{GOAL} agent also has so-called action rules to guide the action selection mechanism.