

## Part II:

# Modeling and Theory of Adaptive and Self-aware Systems

Ensembles face several challenges related to adaptation that are not present for simpler software systems. The second part of the book is therefore devoted to models and theories for self-aware and adaptive systems.

The first chapter reconciles two perspectives on adaptation, black-box adaptation which only takes into account the performance of a system in particular environments and white-box adaptation which classifies the system's data or actions into basic or adaptive activities. The second chapter is concerned with the distribution of knowledge between the components of an ensemble, and in particular the deduction of global knowledge from local representations. It includes a representation for soft-constraint satisfaction problems that can express dynamic programming strategies, which is applied to various optimization problems. The second part of the chapter shows how the techniques can be generalized to problems that are not straightforward optimization problems.

To operate in difficult, changing conditions it is often useful for a component to have knowledge about the environment, the other actors present in the environment, and the ensemble itself. The third chapter introduces KnowLang, a language for knowledge representation. KnowLang provides a comprehensive set of operators to specify logical and stochastic knowledge, to describe the update of knowledge bases and to describe reasoning processes. The chapter introduces the pyramid of awareness and the awareness control loop. The fourth chapter continues the discussion of awareness with a multi-dimensional classification of awareness mechanisms and then focuses on reasoning and learning techniques for achieving awareness and adaptation. It introduces extended behavior trees (XBTs), a graphical language for modeling behavior strategies that include hierarchical reasoning and learning and shows how a novel method for reinforcement learning in cooperative ensembles can be expressed using XBTs. Additionally, mechanisms for integrating on-line and off-line learning in an approach called teacher-student learning are described.

The fifth and final chapter in this part is focused on one particular aspect of awareness that is highly relevant for ensembles consisting of many, often small and energy-constrained, devices: performance. Performance monitoring, measurement evaluation, performance modeling, adaptation and design are described in the context of the ASCENS cloud case study.