Raymond Turner, *Truth and modality for knowledge representation*, The MIT Press, Cambridge, Massachusetts, 1991, xii + 126 pp.

Reviewed by

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This book is included in the MIT Press series Artificial Intelligence edited by Michael Brandy, Daniel Bobrov and Randall Davis. Artificial intelligence is the study of intelligence using the ideas and methods of computation. A definition of intelligence seems impossible at the moment because it appears to be an amalgam of so many information-processing and information-representation abilities. Artificial intelligence offers a new perspective and a new methodology. Its central goal is to make computers intelligent not only to make them more useful but – and this is the point that should be stressed here – to understand the principles that make intelligence possible.

Artificial intelligence requires more expressive systems of knowledge. But there arises a question of whether such systems have to be based on formal logic or not. There are various options. This book, written by Raymond Turner, professor of computer science at the University of Essex, is based on the assumption that the formal approach is a worthy one. Its aim is to explore the development of formal languages and appropriate logics for the aspect of knowledge representation concerned with reasoning about truth and modality. In recent years one can observe a great deal of interest by researchers in the field of artificial intelligence in the development of formalisms which facilitate the expression of modal concepts. These works are based upon the theories of modality and truth which were developed in the period 1960-1980. Turner's purpose is to bring this material to the attention of artificial intelligence researchers by putting it in a context where it might be directly applicable to the knowledge representation used in artificial intelligence.

The book consists of nine chapters which can be divided into four parts: introductory remarks (Chapter 1), the formulation and development of logics of truth (Chapters 2-5), modality and its interaction with truth (Chapters 6-8) and conclusions (Chapter 9). It also contains a list of references, an index of formal terms, and a general index.

Reasoning agents must be capable of representing and reasoning about what they and other agents believe, know and hold true. Hence the central concern of any adequate theory of knowledge representation must be the development of a language in which such assertions as:

Agent A *believes* that *p*
Agent A *knows* that *p*
Agent A *believes* some proposition which is *false*

can be represented together with the formulation of appropriate logics for such modal notions. The development of such languages and logics is the main subject of the book. No definitive answer to the question of which theory is the best one is provided. The author's goal is to draw certain boundaries around the possible form of such theories. He believes that the most natural and computationally tractable theory is a first order one. This imposes some limitations on the logics of modality and truth.

The first half of the book, devoted to the formulation and development of logics of truth, begins with the introduction of the necessary background material on the lambda calculus (syntax, models, semantics) and the predicate calculus, as well as the semantic paradoxes and the Tarski biconditionals (Chapter 2). Chapter 3 is devoted to the development of truth through fixed points, more exactly to a logic of truth **KFG** based upon strong three-valued Kleene logic. In this logic the principle of bivalence: $T(A) \vee F(A)$ (T = true, F = false) must be abandoned (but not the law of excluded middle $A \vee \neg A$). Similarly, the principle **LT** which demands that every logical truth be true has to be eliminated as well. The subject of Chapter 4 is the investigation of a stable theory of truth, i.e. a logic of truth which upholds **LT**. In Chapter 5, the theories of truth due to D. Scott and P. Aczel are studied.

The second half of the book is devoted to modality and its interaction with truth. In Chapter 6 the basic background material on traditional modal logic is reviewed. The possible world semantics and the standard proof theoretic systems of classical modal logic are presented. In Chapter 7 the three theories of truth considered in Chapters 3, 4 and 5 (i.e. fixed point and stable theories of truth as well as the theories of Scott and Aczel) are developed within the context of classical modal logic. This is accomplished by adding a truth predicate to modal logic and investigating the interaction of the logics of truth and modality. In Chapter 8 the alternative approach to modal logic, i.e. the approach in which the modal operators are treated not as one-place connectives but as predicates, is considered. The results and discussions of Chapter 7 are used to guide the search for natural and consistent modal systems of predicative modality.

The conclusions of Chapter 9 offer a retrospective guide through the labyrinth of the logic considered in the book.

In my opinion Turner's book is a valuable contribution to artificial intelligence. It shows how the formal systems of logic can be used and applied to construct theories of knowledge representation. It also includes some of the problems and limitations of these applications as well as possible solutions. As the author writes, [my] "objective has not been to develop definite logics of truth or modality but rather to draw boundaries around what is possible and map out the important features of the logical landscape."