REVIEW: H. van Ditmarsch, W. van der Hoek and B. Kooi's *Dynamic Epistemic Logic*

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REVIEW

Dynamic epistemic logic can be traced back to the works of Hintikka [9] and Pratt [16], but has been flourishing mostly since the turn of the millennium. Even so, a first textbook in the field is felt as having been long-awaited! If only for this reason, this book should be on any (modal) logician's bookshelf.

The main goal of the book is to analyze change of information in a logical setting. Information is treated as being held by agents in the form of knowledge, primarily, but also belief. A convenient way to think of the logical treatment of knowledge in this book is in a stratified way: 1) static knowledge about permanent truths (tautologies or validities) and facts in particular situations, 2) knowledge for groups of agents in the form of common knowledge and 3) dynamics of knowledge with respect to incoming information. This stratification is reflected throughout the book in the various languages adopted, but also in the modular structures of the logics.

This manuscript is meant to be a graduate textbook, but a good background in modal logic in the recent Dutch tradition (cf., [6]) or a supportive instructor are strongly recommended. A decent background in modal logic should be a prerequisite in any case. The topics do not always seem to be presented in the best pedagogical order; references are often made to what will be presented later in the book and this might get a novice reader confused. The English is not always natural and fluctuates in quality depending on various sections or

chapters. The relevence of the book to computer science is made more obvious than to philosophy, although the logics considered raise interesting challenges to mainstream epistemology, namely to incorporate dynamics in standard conception of knowledge. The book is thus lacking in philosophical motivations. The selection of puzzles and illustrations throughout the book, however, is very good and a great tool to assist the assimilation of the material. Each chapter in the book is self-contained (at least with respect to each other chapter and once the content of the first chapter is digested or, better, already assimilated). A course based on this textbook could thus pick any selection of chapters, depending on the course level or quality of students. For the modal logic expert who has not studied dynamic epistemic logic previously, this book is the place to start, although recent developments in the field should be consulted for a fuller picture.

In the rest of the review, I will first give a precis of each chapter (omitting the introductory Chapter 1) and will then suggest additional material that is relevant or untouched in the book.

Chapter 2 gives the basic static system, which is the well-known (multi-) modal logic S5, but interpreted as epistemic logic, in the tradition following the seminal work of Hintikka [9]. Three additional group modalities are then introduced, with A a group of agents: 1) shared knowledge, written $E_A\varphi$ 2) distributed knowledge, $D_A\varphi$ and 3) common knowledge, $C_A\varphi$. The first is defined as the conjunction and the second as the disjunction of each agent knowing that φ, with intended interpretation that every agent knows that φ and that the group of agent knows that φ by combining their knowledge. Common knowledge is a more complex modality and is defined, following Lewis [11], as the limiting case of shared knowledge embeddings: everybody knows that everybody knows that ... everybody knows that φ. This latter modality plays a central role in the remaining chapters and is fully analyzed dynamically. The dynamics of common knowledge is probably the main contribution of the dynamic epistemic logic paradigm.

Chapter 3 is concerned with belief change and the now well-established paradigm of belief revision known as AGM initiated in [1]. AGM analyzes belief change in terms of 3 actions: 1) expansion, 2) revision and 3) contraction of a belief set with a formula φ. The AGM approach is primarily *postulational*, in the sense of providing a set of postulates taken to be rational guidelines for belief change. For instance, the success postulate states that φ should be in the set obtained after revising a belief set with φ. These postulates, however, do not describe nor prescribe a unique belief change operator, and the most common proposal found in the literature, that of *maxichoice*, is presented. The chapter then turns to Segerberg's formalization of AGM in a logical setting, known as *dynamic doxastic logic* (DDL, cf., [12] for a recent exposition with references to previous iterations). DDL is a mixture of conditional doxastic logic interpreted in sphere systems with dynamic modalities, one for each of the AGM actions. This chapter is the most independent from other chapters, and is

the only one that focuses on beliefs. The DDL system is probably what provides the strongest link to the rest of the book, but the chapter would benefit from modern treatments of belief change which would integrate it better in the monograph.

Chapter 4 is a thorough investigation of public announcement logic (cf., [15]) and is the exemplar chapter of dynamic epistemic logic. It is by far the most important chapter for new comers to the discipline. Public announcement is the action of truthfully announcing φ. As opposed to the AGM postulational approach, public announcement is treated in a *constructive* approach and is a fully prescribed action on epistemic models. The action of announcing φ is quite simple: delete all the $\neg\varphi$-states along with accessibility relation to and from these states, but keep the remaining submodel intact. Interesting results with respect to announcements pertain to so-called *unsuccessful* updates, those announcements of φ such that φ is false after the announcement. A typical example is a Moore-type sentence $\psi = \varphi \wedge \neg K_a \varphi$ (φ is true but you don't know it), which can only be performed in states where indeed φ is true and you don't know it, but ψ becomes false after the announcement. This kind of discussion becomes all the more interesting in the presence of common knowledge and a detailed presentation of the issues is provided. The chapter closes with 3 simple, but rich, puzzles: 1) Muddy children, 2) Sum and Product and 3) Russian Cards.

Chapter 5 presents a generalization of the language of public announcement with learning operators, combined with other PDL operators, resulting in a rich language - so rich that it is still unknown how to axiomatize it, unfortunately. This chapter is more difficult (both in content and in reading) than the other chapters and it is advisable to skip to Chapter 6 in an introductory course.

Chapter 6 is the alter-ego of Chapter 4 and presents the other most influential logic in the recent development of DEL. This logic is now known as BMS, after it's authors names (cf., [5]) and this chapter gives it full justice with a full and clear exposition. BMS is a component-wise analysis of static states and epistemic actions. It is an alternative generalization of public announcement logic to the epistemic action system of Chapter 5 which also allows to express complex actions such as private announcement, cheating, learning, etc. BMS has lead to a lot of research recently and I will give some pointers to companion readings for this chapter below.

Chapter 7 is a technical excursion in the completeness results of the various logics studied in previous chapters. It works with a standard canonical model construction or an adaption of the latter construction for non-compact logics (those involving common knowledge). Of notice is the method repeatedly used and sometimes known as 'compositional analysis via reduction axioms', which allows the recursive elimination of action modalities in arbitrary formulas, thus

the reduction of completeness of the dynamic logic to that of the static one. This technique has been applied many times in other dynamic logics of belief and preferences.

Finally, Chapter 8 presents a second technical excursion on the relative expressivity of the various languages used in the book. The results discussed are based on an (obvious) adaptation of Ehrenfeucht-Fraïssé games to modal logic. For instance, it is shown that S5 plus public announcement is equally expressive to S5 without public announcement (which can also be seen via the completeness result with compositional analysis mentioned above), but that S5 plus common knowledge is more expressive than S5 without common knowledge. Surprisingly, the logic K with common knowledge is equally expressive to the logic K with common knowledge and public announcement, although the result is not know in the case of S5. This is an interesting question to be solved by the interested reader or even for graduate students!

A recent development in belief revision, briefly mentioned in the book but which deserves greater attention, is [18]. This paper presents a formalization of belief revision as a proper model change in the constructive approach alluded to above. The axiomatization and completeness uses compositional analysis, which is more in the spirit of the rest of the book. A similar dynamic treatment of preferences can be found in [20]. These two papers show two important kinds of dynamics to be performed on models, in addition to the world deletion of public announcement, namely world reordering (belief revision) and accessibility link deletion (preference upgrade). For an adaptation of the BMS system to belief revision, which would enrich Chapter 3 greatly, see also [2] and further references given there.

Complexity issues pertaining to public annoucement can be found in [14]. Similar complexity questions for the belief revision and preference upgrade actions are still open. A recent and fruitful generalization of the action of public announcement to an action of arbitrary announcement can be found in [4].

Temporal logic (cf., [10]) is not considered in the book, but is an important facet of dynamics. The BMS system is a good starting point to introduce temporal structure in dynamic epistemic logic, as the succession of action is fully encoded in the states. An extended language with a past looking modality, increasing the expressivity of the system, can be found in [21]. A good comparison with epistemic temporal logic (ETL) can be found in [19].

Recent Ph.D. dissertations have been written in the tradition under which the book under review has been written. The reader will find additional references and alternative approaches there. These are [3], [7], [13] and [17].

For the more philosophical reader, a comparison of mainstream and formal epistemology, in particular the role of logic, can be found in [8]. A more thorough comparison of dynamic epistemic logic and mainstream epistemology and the influence that a dynamic twist could have in epistemology is still awaiting.

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