ABSTRACT. Linguistic phenomena of tense and aspect have been investigated in a great deal of theoretical work in linguistics, philosophy and computer science. Modern tense logics, established by Prior, are part of this effort. Point tense logics offer an intuitive representation of tense but lack the expressiveness to represent many aspectual structures. Interval tense logics offer more expressiveness but in the general case can be computationally intractable. From a linguistic perspective there is the problem of precisely how to formalise the aspectual structures, such as a culmination and a culminated process. In this paper we define a computationally tractable augmented fragment of Halpern and Shoham’s interval tense logic HS and apply it to represent a core set of aspectual structures, which are incorporated into a temporal semantics of a simple fragment of English. We model the logic fragment using timelines and define two procedures, one for constructing the minimal timelines that satisfy a formula and one for checking semantic entailments between one formula and another by comparing their timelines. The former is applied to compute models of temporal readings and the latter to check entailments between them. Possible extensions to the logic fragment and timeline models are discussed as ways of accounting for a wider range of linguistic behaviour.

1. INTRODUCTION

In natural language we convey temporal information through a variety of linguistic categories, such as the simple tenses (past, present and future), the progressive, the perfect, adverbial phrases, conjunctions and determiners in noun phrases. By formalising theories of tense and aspect in terms of logics one may gain insight into how humans may understand, organise and generate the temporal information present in sentences and narratives. Modern tense logics, established by Prior in the 1960s (see Prior (1967)), are motivated by the study of these phenomena. Prior held that logic should be related as closely as possible to intuitions embodied in everyday discourse. Point tense logics have succeeded in this respect with regard to tense, but lack the expressiveness to represent the range of aspectual
structures required in a wider theory. Interval logics are more expressive but in the general case can be computationally intractable. As well as the question of tractability there are more linguistic questions regarding how to represent a core set of aspectual structures that includes the culmination and culminated process.

In this paper we develop representations and models of aspectual structures starting from related work in tense and aspect (Section 2) and Halpern and Shoham’s interval tense logic HS (see Halpern and Shoham (1986), also summarised here in Section 3). We first define a fragment of HS called HSF1, describe how to model it using timelines and show how to automatically construct the timelines the satisfy a formula (Section 3). We then augment the fragment with a focus operator to create a new language HSF1A, and apply HSF1A to represent a number of aspectual structures, the perfect and simple tenses (Section 4). Following this we demonstrate a straightforward link between our representations and natural language via a temporal semantics for a fragment of English, and in Section 5 we demonstrate how linguistic entailments can be checked automatically by comparing the timeline models of the temporal readings of sentences. Section 6 concludes the paper.

2. RELATED WORK ON TENSE AND ASPECT

In this section we give brief summaries of the work of eight researchers that is of particular significance to ours: Reichenbach (1947), Prior (1967), Vendler (1967), Kamp (1968), Moens (1987), Lascarides (1988), Kent (1993) and Verkuyl (1993).

2.1. Reichenbach

Reichenbach’s characterisation of tense in Elements of Symbolic Logic, Reichenbach (1947), has had lasting influence on later theories. In it he argues that there are three times underlying tense, rather than two, namely the speech point (S), event point (E) and reference point (R). The reference point, denoting the time being referred to in the utterance, is Reichenbach’s main innovation. The other points (or equivalent concepts) had been around for some time. In Reichenbach’s theory, the event point and reference point coincide in the case of the simple tenses (past, present and future) whereas in uses of the perfect such as the past perfect and the present perfect, the event point and reference point are distinct (see Figure 1). Later work has shown how Reichenbach’s theory can be exten-