Abstract

Linear tense logics are widely accepted for structural temporal representation, where the basic K_T has two modal operators G and H, each of which represents the future and the past, respectively. Closely related to modal logics, it has been studied for a long time. We need to analyses the uses of the tense and aspect of the language in order to prepare it for the computer. This is aside from the theoretical value of studying the logical structure of time use in language. Thus far, many linguists and computer scientists have proposed the temporal relations in occurrences. Each occurrence of an event happens once and for all, and the events may have causal relations or other kinds of information flow in them. Especially, linear tense logics are well known as logics deal with time as a set of points. On the other hand, there is an another approach to temporal reasoning which takes as primitive temporal intervals rather than points. These logics are well known as temporal logics which have binary relations for the relations between temporal intervals. At first, in this study, we show the logic of occurrence which has the temporal heredities for a temporal structure. We represent them by the binary relations because of a temporal heredity is associated with temporal interval logics. Thus, temporal intervals are given by a set of events, and the relationship in temporal intervals are defined also by those in events, i.e., a set of events articulates the time axis. We summarize temporal relations in occurrences, give the syntax and the semantics of the language for the occurrence logic, incorporating the concept of temporal heredity into it. And we explain the logic programming system based on the formal language.

The temporal interval relations arranged by Allen have long been the standard of natural language semantics, though it still lacks the modal-logical foundation. So, in our occurrence logic, the temporal relations between temporal intervals are utilized as the binary operators. Van Benthem proposed $\square^{up}$ and $\square_{down}$ in regard to the accessibility to overlapping intervals and subintervals, respectively; however, the logical feature of the modality has not well studied. So, in this study, we define the modal operators for the above temporal relations, propose a many-dimensional propositional temporal logic $K_{T\square}$ including the conventional tense logic, together with such interval accessibility. $K_{T\square}$ is a combined logic of conventional tense logics and temporal logics by *fusion*. For example, introducing a *precedence* relations $\prec$ and $\succ$ in two occurrences, we use a temporal operator G and H. Furthermore, introducing an *inclusion* relations $\subseteq$ and $\supseteq$ in two occurrences, we define $\square^{\uparrow}$ and $\square_{\downarrow}$ and use them. We summarize accessibility relations for $\succ, \prec, \subseteq$, and $\supseteq$ between possible worlds, give the syntax and the semantics of the language for $K_{T\square}$, and we show our logic can represent the temporal heredities by the newly-formed temporal operators. Moreover, we introduce a sequent system for $K_{T\square}$ and show a proof-search procedure. Additionally, we show the subformula property holds in our system, and thus would be able to show the decidability. Next, we show that our logic provide a formal apparatus for a precise aspectual classification. We show some formulae by our logic express some aspect classes by Vendler such as *event*, *state*, *achievement*, and so on. Furthermore, we can hypothesize the starting/ending points by assuming a certain superinterval by "$\varphi \Rightarrow \Diamond^{\uparrow} \square_{\downarrow} \varphi,$" where $\Diamond^{\uparrow}$ is an abbreviation of $\neg \square^{\uparrow} \neg$ and denotes some possible world which includes the assumed starting/ending points. In the similar way, we assume a minimal interval. Especially, we can regard "$\varphi \Rightarrow \Diamond_{\downarrow}(H \neg \varphi \wedge \square^{\uparrow} \varphi \wedge G \neg \varphi)$" as a representation of the *culmination* where $\Diamond_{\downarrow}$ is an abbreviation of $\neg \square_{\downarrow} \neg$. Generally speaking, we cannot measure the *exact* size of the temporal location of an occurrence. However, by our logic, we can hypothesize the starting/ending points by assuming the certain possible worlds for a state and a event. We show such an aspectual classification and some temporal features by our logic. Furthermore, we propose $K_{T\square}^{+}$ by adding some axioms for $K_{T\square}$. Because of $K_{T\square}$ is given by the simplest fusion, which is axiomatized by the union of axioms of a tense logic and a temporal logic, G, H and $\square^{\uparrow}, \square_{\downarrow}$ are not independence temporally, we need to introduce some axioms including these modal operators simultaneously, and show the power of temporal expression of $K_{T\square}^{+}$.