Analyzing Japanese Relative Tense with Dependent Type Semantics

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Introduction Tense is a "dynamic" phenomenon in that its interpretation depends on context, in a manner similar to anaphora (Partee, 1973). In order to analyze such dynamic phenomena, some researchers have proposed using dependent type theory (Ranta, 1995; Sundholm, 1986). In particular, *Dependent Type Semantics* (DTS) (Bekki, 2014; Bekki and Mineshima, 2017) provides a fully compositional account of anaphora and presupposition. Thus, such type-theoretical formal semantics will also offer a promising approach to the interpretation of tense. This paper describes the current status of our research toward a type-theoretical and compositional analysis of tense, which focuses on the phenomenon called *relative tense* in Japanese.

Relative Tense in Japanese Tense locates events and states with respect to a particular time called the *evaluation time*, regarding which it is classified into two types: *absolute* and *relative* tense (Comrie, 1985). While the evaluation time of absolute tense is the speech time, that of relative tense is provided by the context, not limited to the speech time.

One set of examples of relative tense is seen in Japanese subordinate clauses (Ogihara, 1996). To see this, let us consider the following pair of sentences with a relative clause, where the only difference is the tense form of the matrix clause.[1]

(1) a. [ki-ta (t_2) kodomo] ga hasit-**ta** (t_1)
come-PST child NOM run-PST
"A child who {had come/came} ran."

b. [ki-ta (t_2) kodomo] ga hasi-**ru** (t_1)
come-PST child NOM run-NPST
"A child who {came/will come} will run."

Both of these two sentences are ambiguous between two readings, but in different ways, which are depicted graphically in Figure 1.

[1]Japanese has two tenses: *past* and *nonpast*, indicated in glosses as PST and NPST. Note also that Japanese has no overt relative pronouns.

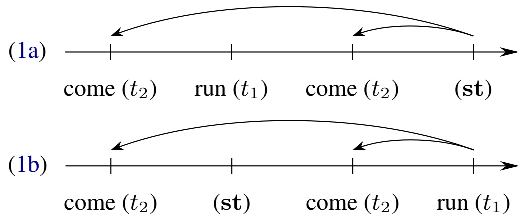

Figure 1: The difference between (1a) and (1b) in temporal interpretation, where the arrows represent the evaluation of tense: the evaluation time of the relative clause is **st** (the speech time) in (1a) and t_1 in (1b).

We can see that the evaluation time of a relative clause can differ according to the tense form of its matrix clause. The same phenomenon is also observed in other types of subordinate clauses in Japanese, for which Mihara (1992) provided a descriptive analysis.

What is crucial here is that the evaluation time of a subordinate clause cannot be determined without its matrix clause. Due to such dynamic behavior, it is challenging to provide a compositional analysis for relative tense. More specifically, we need a mechanism that enables us (i) to check the tense forms of both matrix and subordinate clauses, and (ii) to keep the evaluation time underspecified when the subordinate clause is constructed, and determine it after we have obtained the result of (i).

Dependent Type Semantics DTS is a compositional semantics based on dependent type theory (Martin-Löf, 1984). The main feature of DTS is an *underspecified term*, written as $@ :: A$, which serves as a placeholder to be filled later by a concrete term of type A. For instance, the discourse (2a) is translated into the semantic representation (2b), where $@ :: \mathbf{entity}$ represents *she* and the type $\begin{bmatrix} x : A \\ B \end{bmatrix}$ corresponds to $\exists x \in A.B$.[2]

[2]This type is defined to be the type of pairs $\langle a, b\rangle$ with $a : A$ and $b : B[x := a]$. Note that it corresponds to $A \wedge B$ if x does not occur free in B (in which case we write $A \times B$). We refer the reader to Tanaka (2021) for formal details.

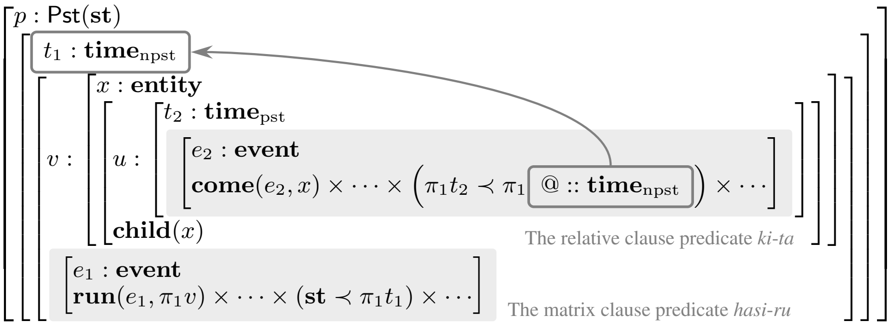

Figure 2: The semantic representation of (1b). t_1 and t_2 (resp. e_1 and e_2) are existentially quantified and represent the time (resp. event) of the matrix and relative clause.

(2) a. A[1] child came. She$_1$ ran.

b. $$\begin{bmatrix} v : \begin{bmatrix} u : \begin{bmatrix} \boxed{x : \mathbf{entity}} \\ \mathbf{child}(x) \end{bmatrix} \\ \mathbf{come}(\pi_1 u) \end{bmatrix} \\ \mathbf{run}\left(\boxed{@ :: \mathbf{entity}}\right) \end{bmatrix}$$

An underspecified term is substituted with a concrete term in the context. In (2b), we can replace @ with the term $\pi_1\pi_1 v$, where π_1 is the function that takes the first element of a pair. This term corresponds to x : **entity**, as the arrow indicates, which captures our intuition that *she* refers back to *a child*.

One advantage of DTS is that the above process of anaphora resolution is implementable using the mechanism of *type checking* and *proof search* (see e.g., Bekki and Satoh (2015) for an actual implementation). In addition, it has been argued that DTS can solve particular empirical problems with some other dynamic semantic frameworks (Yana et al., 2019).

Regarding tense, Utsugi (2017) proposed *tensed DTS* as an extension of DTS with the type of time intervals **time**, and provided a general analysis of the Japanese tense system. Our goal is to extend tensed DTS and provide a compositional account for the behavior of relative tense.

Proposal Our proposal is twofold.

(i) The tense form of a predicate (i.e., past or nonpast) is recorded in the semantic representation of the clause containing the predicate.

(ii) The evaluation time of a subordinate clause is represented as an underspecified term.

As to (i), we formally define the following types, extending the time-interval type **time**.

$$\mathbf{time}_{\mathrm{pst}} \stackrel{\mathsf{def}}{=} \begin{bmatrix} x : \mathbf{time} \\ \mathsf{Pst}(x) \end{bmatrix}, \quad \mathbf{time}_{\mathrm{npst}} \stackrel{\mathsf{def}}{=} \begin{bmatrix} x : \mathbf{time} \\ \mathsf{Npst}(x) \end{bmatrix}$$

Intuitively, the one-place predicate Npst (resp. Pst) expresses the property of being introduced by a nonpast (resp. past) predicate. These two types allow us to handle the tense forms of predicates at the semantic level.

To illustrate (ii), let us consider the example of relative tense (1). We first construct the semantic representation of *ki-ta kodomo* as follows.[3]

$$\lambda x. \begin{bmatrix} u : \begin{bmatrix} t_2 : \mathbf{time}_{\mathrm{pst}} \\ \begin{bmatrix} e_2 : \mathbf{event} \\ \mathbf{come}(e_2, x) \times \cdots \\ \cdots \times \left(\pi_1 t_2 \prec \pi_1 \underline{@ :: \mathbf{time}_{\mathrm{npst}}}\right) \times \cdots \end{bmatrix} \end{bmatrix} \\ \mathbf{child}(x) \end{bmatrix}$$

The point here is that we define the evaluation time of the relative clause *ki-ta* to be $@ :: \mathbf{time}_{\mathrm{npst}}$ (underlined above), annotated with the opposite type of $t_2 : \mathbf{time}_{\mathrm{pst}}$. Using an underspecified term, we can keep the evaluation time undetermined and capture the dynamic character of relative tense.

Then, we observe the case of (1b), where the evaluation time is the matrix clause time. We show the outline of its semantic representation in Figure 2. The arrow indicates that $@ :: \mathbf{time}_{\mathrm{npst}}$ is resolved by t_1 (i.e., the matrix clause time), as expected.

With regard to (1a), where the evaluation time is the speech time, the same strategy is not applicable because t_1 here has type $\mathbf{time}_{\mathrm{pst}}$, not $\mathbf{time}_{\mathrm{npst}}$.

$$\begin{bmatrix} p : \mathsf{Npst}(\mathbf{st}) \qquad \boxed{\langle \mathbf{st}, p \rangle} \\ \begin{bmatrix} \boxed{t_1 : \mathbf{time}_{\mathrm{pst}}} \\ \cdots \begin{bmatrix} t_2 : \mathbf{time}_{\mathrm{pst}} \\ \cdots \times \left(\pi_1 t_2 \prec \pi_1 \boxed{@ :: \mathbf{time}_{\mathrm{npst}}}\right) \times \cdots \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Instead, we can use the variable p (introduced in the matrix clause) and construct the term $\langle \mathbf{st}, p \rangle$:

[3]In this study, we use Combinatory Categorial Grammar (Steedman, 2000; Bekki, 2010), a lexicalized grammar, as the syntactic theory. We omit the details of lexical entries.

$\mathbf{time}_{\mathrm{npst}}$. From $\pi_1\langle \mathbf{st}, p\rangle =_\beta \mathbf{st}$, we obtain the correct prediction that $\pi_1 t_2 \prec \mathbf{st}$, that is, the evaluation time is $\mathbf{st}$.

The above argument also works when the relative clause has the nonpast form. In addition, the same idea of using @ can be realized in essentially the same way for other subordinate clauses discussed by Mihara (1992) (e.g., appositive clauses, quotation clauses).

Conclusion This paper presented our current analysis of Japanese relative tense using DTS. We proposed determining the evaluation time of a subordinate clause with an underspecified term @ annotated with a type containing the information of the tense form. We demonstrated that this method correctly predicts the behavior of relative tense described by Mihara (1992).

In future work, we will investigate the temporal relations in multiply embedded clauses, which will require a generalization of the observation by Mihara (1992). Another future direction is to expand our proposal to temporal clauses (e.g., *mae-ni* (before)), which show peculiar behavior involving interactions between tense and aspect (Kaufmann and Miyachi, 2011; Oshima, 2011).

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