The Right Frontier Constraint Holds Unconditionally

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Abstract

The paper re-opens the controversial case of the right frontier constraint. A formal proof of its applicability in models that use certain types of trees as modalities to represent the structure of discourse is given. Then its violation, reported to occur in discourses "under pressure", is revisited and a proposal for discourse structure representation that deviates from classical trees is made.

1 Introduction

There are two situations when one can associate a data structure type with a process intended to put in evidence the structure of the discourse (as a discourse parser): at any moment during the interpretation of the discourse and at the end of the interpretation process. If the interpretation of the discourse structure is modelled to be synchronous with a cognitive process (like reading or listening) we have an incremental type of discourse processing. One fundamental property of the discourse trees that is supposed to hold in both the intermediate and the final situations of the tree as a representation of the structure is the **Sequentiality Principle** (SP), (for instance, (Marcu, 2000)). It states that:

> *A left-to-right reading of the terminal frontier of a discourse tree associated to a text corresponds to the span of text analysed, in the same linear order.*[1]

The Right Frontier Constraint (RFC) is mentioned in discourse in two settings: as an attachment constraint in an incremental discourse development of the tree structure (for instance, (Cristea and Webber, 1997)), and as a referential constraint defining the regions of the discourse model taken to be in focus, therefore introducing discourse entities which are recoverable by referential expressions contained in the last mentioned discourse unit (Polanyi, 1988; Webber, 1991). RFC has recently received new attention among scholars preoccupied to model the discourse phenomena (Asher and Lascarides, 2003; Sassen and Kühnlein, 2005), in relation to the discovering of counter-examples in corpora of chat communication.

In this paper, a formal proof on the applicability of RFC over discourse trees that observe the SP is given (section 2) and a proposal of enhancement of the representation by replacing trees with graphs is made (section 3).

2 Why cannot the Right Frontier Constraint be violated?

In both settings mentioned above, RFC is empirically defended based on observations over linguistic material. However, it is easy to formally prove this discourse property once one agrees to operate

[1] Many authors suppose this principle holds in most cases. The problems are given by the interrupted sentences. In most annotation conventions applied to discourse structure (see, for instance, the RSTTool of Michael O'Donnell (1997), the constituent parts are linked in chains using attributes like `Same-Unit`, etc.).

only with discourse trees observing the SP. The formal prove follows below as the natural yield of a sequence of propositions. In discussing the incremental development of a discourse tree, two operations are considered, usually mentioned by researchers dealing with incremental discourse parsing: adjunction and substitution, inspired by tree adjoining grammars (TAG) (Joshi, 1987).

In processes of this type it is clear that the final discourse tree is obtained after the last step of the process and that, at any intermediate moment, a partially developed discourse tree reflects the interpretation that the listener has on the discourse heard so far. There is, to my knowledge, little corpus evidence for a “garden path” behaviour at the level of discourse understanding that would impose to the incremental model to accommodate a way of reconsidering the structure build so far. However, a certain buffering mechanism able to integrate new material onto the already developed structure in greater chunks than the minimum text span used to represent a leaf tree node would always allow for a smoother advancement towards the final structure. Şoricuț and Marcu (2003) present corpus evidence that in 95% of the cases there is always a tree node covering a sentence, which suggests to consider the dimension of the sentence as the advancing buffer.

Our argument applies to discourse trees at any step during an incremental developing process. We will give first some definitions.

The **right frontier** (RF) of a tree is the sequence of nodes that starts in the root of the tree and continues with all nodes placed in the right extreme of the tree at any level. The **terminal frontier** (TF) is the sequence of nodes, counted left-to-right, on the lowest levels of the tree (therefore which do not have any daughters).

Adjunction (see Figure 1a) operates on two trees: a **developing tree** (DT) produced so far during parsing (called “initial tree” in TAG) and an **auxiliary tree** (AT), which is being contributed by the current minimal chunk of text under processing. The auxiliary tree is "inserted" in the DT at the level of a certain node of DT. The auxiliary tree owns a special node placed on its terminal frontier, called **foot node**, and marked ✻ in Figure 1 and following, whose role is to take over the sub-tree of the initial tree "cut" by the operation of adjunction. An AT whose foot node is placed in the left extremity of its terminal frontier will be called **left-footed auxiliary tree**. The TAG restriction that the root and the foot nodes of the AT have the same label does not apply here. This implies that none of the formal properties that were proved to hold for TAGs are supposed to hold in our setting. Only the cutting and insertion machinery is kept.

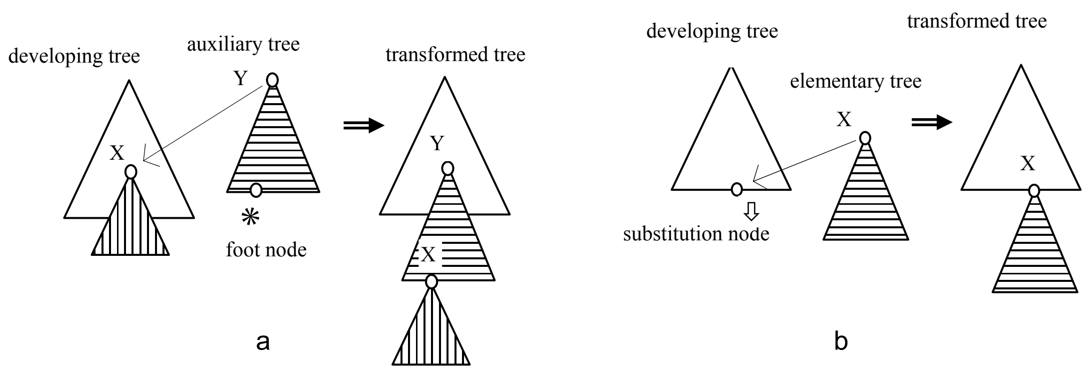


Figure 1. Adjunction (a) and substitution (b).

Substitution (see Figure 1b) is the operation by which a tree, called **elementary tree**, replaces a node, called **substitution node**, and noted ⇩ in Figure 1b, placed on the right extreme of the terminal frontier of the DT.[2]

In what follows all nodes are supposed to be marked with a label. A sequence of nodes is also represented by the sequence of their labels. First, we will give without proof some evident properties of tree adjoining.

[2] Although mentioned here, we will ignore in this study the use of substitution.

Proposition 1: If the root node of a tree τ has as daughters the nodes a_1, …, a_n (in this order, from left to right) and the TF frontier of the tree with root a_i is the sequence of nodes σ_i, for each i=1 to n, then the TF of tree τ is $\sigma_1 \circ \ldots \circ \sigma_n$ (see Figure …), where "$\circ$" is the string concatenation operation.

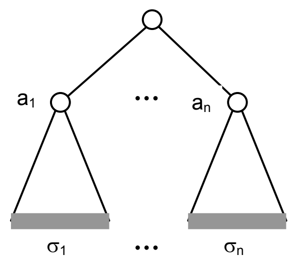


Figure 2. Adjacency of siblings is reflected as adjacency of covered spans.

Proposition 2: If an AT with the terminal frontier $\sigma_1 \circ * \circ \sigma_2$ is adjoined at the position of the root of a DT having the terminal frontier σ_0, then the terminal frontier of the resulting tree is $\sigma_1 \circ \sigma_0 \circ \sigma_2$ (see Figure 3a).

Proposition 3: In any span of text σ whose discourse structure is the tree τ, any node of its right frontier covers a right substring of σ (see Figure 3b).

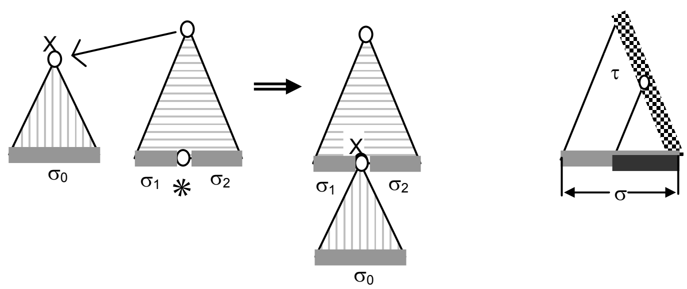
The announced Right Frontier Property can now be proved.

The Right Frontier Property: At any step of an incremental discourse parsing, if the DT does not contain substitution nodes, the SP is observed if and only if all operations are adjoinings of left-footed ATs onto nodes of the right frontier of the DT.

Proof:

⇦ If the adjoining is realised with a left-footed AT on the right frontier of the developing tree, then the SP is observed. The property results by virtue of Proposition 3. As can be noticed on Figure 4, the TF of the resulting tree is $\sigma' = \sigma_0 \circ \sigma_1 \circ \sigma_a$, in accordance with the SP.

⇨ We will show that any adjunction operation other than that of a left-footed AT on a node of the RF of the DT contradicts the SP. There are two cases to consider:



a. b.

Figure 3. Adjoining properties in trees.

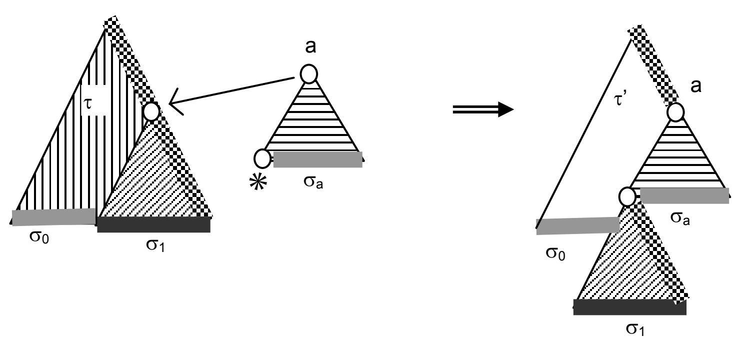


Figure 4. Adjunction of a left-footed AT on the RF of the DT.

- the adjunction of an AT which is not left-footed on the RF of the DT, and
- the adjunction of an AT of any kind in a node of the DT which does not belong to its RF.

Case a. follows from both Proposition 2 and Proposition 3 (notice the notations on Figure 5a): by adjoining the AT (with the TF $\sigma_{a1} \circ * \circ \sigma_{a2}$) on a node a_1 (covering the TF σ_1) belonging to the right frontier of the DT, the TF modifies from $\sigma_0 \circ \sigma_1$ to $\sigma_0 \circ \sigma_{a1} \circ \sigma_1 \circ \sigma_{a2}$, thus violating the SP. The correct order would have been $\sigma_0 \circ \sigma_1 \circ \sigma_{a1} \circ \sigma_{a2}$, while now the nodes of σ_1 are intercalated between σ_{a1} and σ_{a2}.

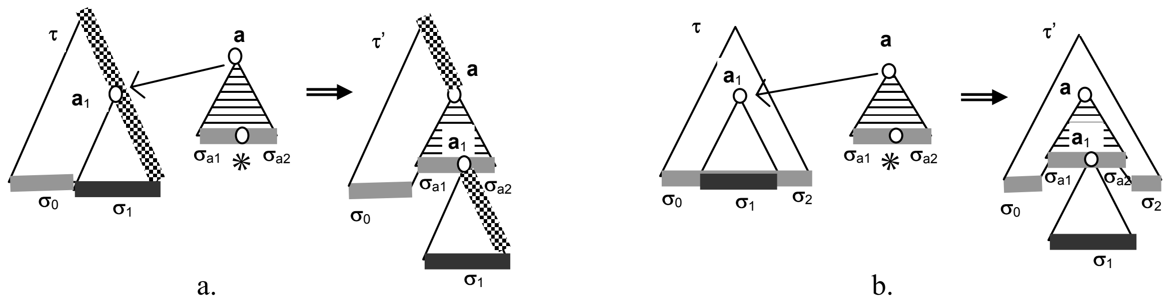


Figure 5. Cases that result in violation of the SP.

Case b. follows from a recursive application of Propositions 1 and the properties of string concatenations (notations in Figure 5b): if the adjoining of an AT (with the TF $\sigma_{a1} \circ * \circ \sigma_{a2}$) is done on a node a1 of the DT (covering the TF σ_1), then the TF develops from $\sigma_0 \circ \sigma_1 \circ \sigma_2$ to $\sigma_0 \circ \sigma_{a1} \circ \sigma_1 \circ \sigma_{a2} \circ \sigma_2$, which also violates the SP, the correct order having to be $\sigma_0 \circ \sigma_1 \circ \sigma_2 \circ \sigma_{a1} \circ \sigma_{a2}$.

3 On the violation of the RFC

Violation of the RFC has been recently reported by some researchers, as Asher and Lascarides (2003) and Sassen and Kühnlein (2005), after studying corpora of chat communication. Sassen and Kühnlein explain this finding by the pressure to keep the channel open or to signal presence on chat dialogue, as opposed to face-to-face dialogue or monologue. They complement the classical RFC with a conditional, expressing the absence of pressure. By doing this, however, we are left with wild possibilities of conducting dialogues in cases when pressure exists. Indeed they say: if the absence of pressure condition is not satisfied, therefore if we are under pressure, the RFC does not apply.

Lets take one of their dialogues and complement it with more text at the beginning:

Example 1

a1. B: I've recently felt confused when seeing Maria talking with Michael.

b1. B: The reason I'm asking your advise is that I'll have my degree in June and right now I'm not in my best shape.

a2. A: oh yea, then, what we have here is a nice case of jealousy.

a3. B: would you say that I'm indeed only jealous?

c1. B: do you have another consultation hour scheduled soon?

b2. A: Try to be with yourself after all you're heading for your final degree!

b3. B: mhm, well, but concentrating on my studies often doesn't work

c2. A: yes, always on Monday.

a4. A: only jealous that would already suffice as problem, but I think there is more to it.

Starting from a3, Example 1 displays the same dialogue as in their corpus. I have marked the three separate threads (themes) with the indices a, b, c and numbered them in sequence. Suppose now that the dialogue would go on like this:

A: to this you have to find a solution immediately.

At this point *this* would have been understood as either *adding to B's problems his recent jealousy*, following the thread a, or that *concentrating on B's studies doesn't work*, following the thread b. There is no way however in which *this* could have been understood to mean *the meetings between Maria and Michael* (in the sense to intervene for putting an end to them) or *not being in B's best shape*.

What I'm trying to convince the reader is that in communications that fit the "pressure" pattern, as those displayed by chats, different themes could be interleaved, while, however, each of them do still observe some kind of RFC restrictions which seem to apply to individually developing trees. It seems that the human mind has the capacity to record and follow more communication threads in parallel, in each of them the discourse unfolding by respecting the basic principles of well-formedness[3]. A model for this behaviour can again be expressed by the old tree structures observing the SP and the RFC, with the only change that each communication thread develops its own tree.

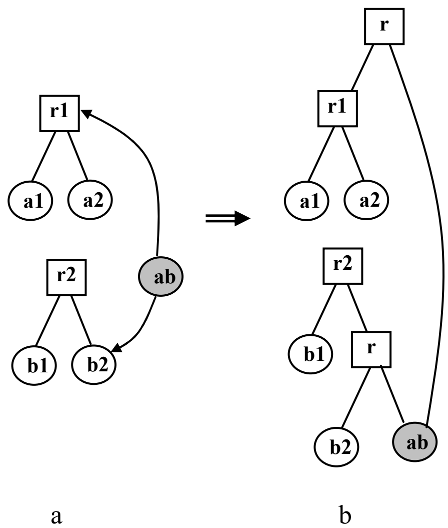


Figure 6. Merging of two DTs.

Two operations can apply over discourse trees developing in parallel: **merging** and **splitting**. When one AT adjoins simultaneously onto two (or more) nodes belonging to different but parallel communication threads, the corresponding DTs merge. Consider the example:

[3] I thank to an anonymous reviewer who noticed that in case of chats the memory of the conversation could be helped also by the history displayed on the screen.

Example 2

```
  a1. A: how was your trip to Braşov?
  b1. A: oh, did I tell you? I have
seen yesterday evening Michael in the
disco.
  b2.    did you meet him anymore
since you two split?
  a2. B. Fantastic! lot's of nice
guys and lot of fun.
  ab.    wow, but, you know, he was
too in that trip!
```

The two evolving trees before ab are sketched in Figure 6a, while the resulting graph after the merge – in Figure 6b.

At times, the dialogue can evidence different threads, all evolving from a common trunk. Consider the following chat:

Example 3

```
  ab1. A: so, you didn't know that I
finished with Michael?!
  ab2     it happened last month af-
ter I came back from Mexico.
  a3.  B: oh, I'm sorry, are you
still mourning after him or you have
already someone else?
  a4.  A: negative! I'm ok and need a
period of loneliness.
  a5.  B: you cannot resist long like
this. I know you…
  b3.     so, have you seen the pyra-
mids there?
```

It is not unusual that a dialogue communicates ideas or situations which, although different, are tightly interleaved, configuring, therefore, just one communication thread. In such a dialogue it is also possible that, at a certain moment, two separate themes diverge. In Example 3, ab1 and ab2 do still belong to the same thread, as signalled by the anaphoric pronoun *it* in the second sentence which is anchored in the first sentence. Then a3-a5 develop on the separation of A from Michael, while b3 refers back to A's trip to Mexico, making evident the yield of a separate thread. However, each of the two threads still obey to the RFC behaviour. Put in terms of discourse structures, this means that a developing tree structure suffers a split at a certain

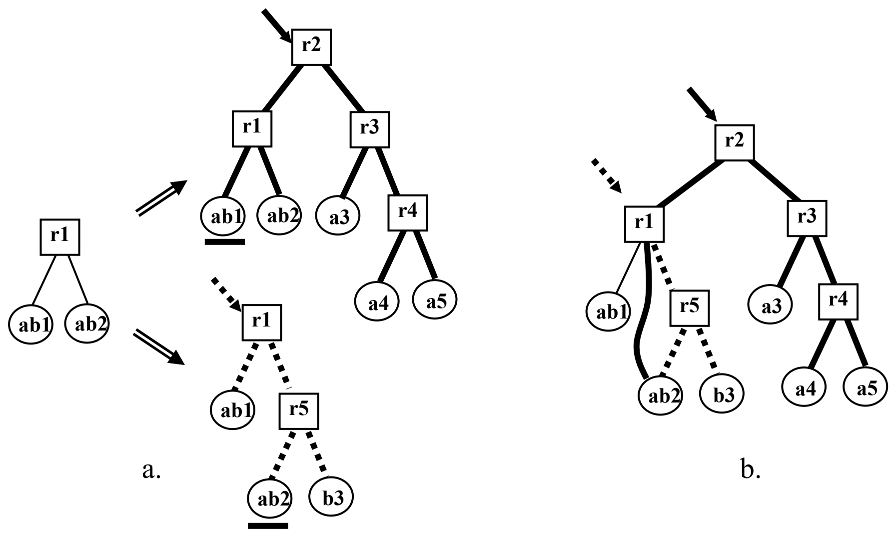


Figure 7. Splitting a DT onto two separate threads.

point, allowing for asynchronous ulterior unfolding, as in Figure 7.

Figure 7a shows the two ways in which the initial tree made of ab1 and ab2 can evolve. In the upper tree, a3 is adjoined at the top most node r1 (since it elaborates on the separation from Michael narration communicated by the sequence ab1-ab2), while the following nodes, a4 and a5, are each adjoined at the bottom most nodes on the right frontier of their DTs (since both complement with more details their previous turns, on the same "Michael" story). In the lower tree, b3, detailing the Mexico trip mentioned in ab2, is adjoined at this last node. In both trees the roots and the edges are marked in distinguished patterns. These markings will allow computing two different right frontiers on the graph of Figure 7b, obtained after splitting the evolving tree structure onto two separate threads. In practice, in an incremental development of the discourse structure, the graph, as displayed in Figure 7b, is built incrementally.

The problem with this approach is that, at the very moment of splitting the tree onto a graph, the RFC seems to be violated. Indeed, how can we explain the adjoining of b3 onto the ab2 node, whish is closed at the moment when b3 is uttered (see the upper tree in Figure 7a)?

I will comment on this apparent contradiction by bringing into focus those theories of the relationship between discourse structure and referentiality which, modelling the dynamics of discourse processing, accommodate the observation that, at any moment during interpretation of the discourse, the hearer can access, using weak referential means, only certain parts of the past discourse, while others are obscured. In accordance also with other researchers (Gundel et al., 1993), by weak referential means I understand referential signallers that point at previously introduced discourse entities by describers displaying not-at-all or poor semantic features, as pronouns or demonstratives. Their use relies on the sufficiency of the focus mechanism as a delimitating tool[4]. In contrast, rich referential means are referential expressions that individuate an entity among many in terms of properties of the individual having to be singled out[5]. They can be proper nouns and noun phrases that exhibit a lexical and/or an ontological relation with the name of the pointed discourse entity. In (Grosz and Sidner, 1986), the focusing effect in the dynamics of discourse interpretation is modelled by a stack of attentional states, the newest ones appearing on top of the older ones. In (Cristea et al., 1998) the

4 Imagine a pool of objects of different forms and colors, among which one should be indicated, and a lantern beam moving above them and, so, individuating in turn, one or another. In this situation a verbal expression may sufficiently signal only the moment when the pointing should be considered, the individuation of one element among many being made by the focussing beam itself.

5 This is always the case when the object to be indicated is outside the lantern beam or there are more than one object lightened by the spot.

focussing effect is obtained by considering part of the vein expression, computed on the base of the discourse structure, which is made of elementary discourse unit the referring expressions belong to.

Remember also that there is a nuance in the formulation of the RFC: most people recognise that, if the principle is violated, the obtained discourse is less readable, and not that it is completely unacceptable. Sometimes, when RFC is violated we feel like we need to put to work some more inferential machinery in order to understand the discourse. Some other time, the discourse fails. In the example above we do not have this latter case: the dialogue can be understood, apparently even without the need to bounce back in order to localise the referent for *the pyramids there*. The reason is that the referential expression *the pyramids* is a very powerfully evoking one. It resonates instantly and unambiguously with *Mexico* from the previous discourse. If, instead, the last turn would have been *how often have you been there?* the discourse would be perceived as failed, because no link could have been found with an entity contributed by the nodes on the RF and the question contains nothing powerful enough to evoke unambiguously an entity in the rest of the discourse.

So, the conclusion is that discourse trees can split in points localised by powerful evoking means in past discourse.

4 Conclusions

In discourse processing, the Right Frontier Constraint plays a prominent role at least from two perspectives: a theoretical one, by offering explanations for the choices humans make in using linguistic pointers, as pronouns or demonstratives, and a computational one, by offering a strong condition which significantly reduces the indeterminism in processing. Recently, evidence has been found in chat corpora, which militates apparently against this constraint. In these examples, dialogues display intertwined turn-taking, which seem to minimize the RFC behind a condition of applicability (Sassen and Kühnlein, 2005). However, the introduction of this condition leaves "pressure" dialogues completely unconstrained, which is unrealistic. The paper rehabilitates the applicability of the Right Frontier Constraint in all cases of discourse interpretation, by formally proving that whenever the discourse structure is represented as a tree that obeys the Principle of Sequentiality by its terminal nodes, adjoining, as an operation of incremental tree development, should always be applied onto a node belonging to the right frontier. Examples are given that demonstrate that even in cases of intertwined chats the RFC still applies if considered on individual thematic threads. We propose to replace discourse trees by discourse graphs on which RFC can again be verified. First, intertwined different themes are represented by distinct trees, each of them obeying the RFC. Second, during discourse unfolding, when different themes, representing distinct dialogue or monologue threads, approach, their corresponding trees can merge in a discourse graph in which common nodes are represented uniquely. Third, from one developing tree structure, a graph could yield, at moments when the theme diverges onto two separate threads. The splitting is announced by powerful evoking referential means which do not find their corresponding antecedents on the right frontier.

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