Refining Tabular Parsers for TAGs

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Abstract

This paper investigates several refinements of a generic tabular parser for Tree Adjoining Grammars. The resulting parser is simpler and more efficient in practice, even though the worst case complexity is not optimal.

1 Introduction

In (Villemonte de la Clergerie and Alonso Pardo, 1998), we have presented a generic Dynamic Programming [DP] interpretation for 2-Stack Automata [2SA]. These automata may be used to describe various kinds of parsing strategies for Tree Adjoining Grammars [TAG] and Linear Indexed Grammars [LIG], while the DP interpretation ensures the existence of tabular parsers satisfying the prefix-valid property and running in (optimal) worst-case time complexity $O(n^6)$ and space complexity $O(n^5)$ where n is the length of the input string.¹ An implementation, extended to handle unification, has been realized within DyALog system and tested for Feature TAGs (Alonso Pardo et al., 2000).

However, our analysis of that work was that the DP interpretation is relatively complex and the results not convincing. We believe that one reason for that is that the original DP interpretation was designed for 2SAs in general and does not take into account the particularities of TAGs. By analyzing how information is used when parsing TAGs, we are able to weaken the original DP interpretation. The new interpretation, while not ensuring optimal worst-case complexity w.r.t. the length of the input string (but still a polynomial one), has shown better performances for realistic linguistic grammars and sentences.

The paper begins, in Section 2, with a brief introduction to TAGs. Section 3 shows how parsing TAGs may be described using a 2-stack automaton. Section 4 presents the original “*strong*” DP interpretation. Section 5 shows how a “*weaker*” DP interpretation may be derived. Results are provided in Section 6.

¹Note that the optimal worst-case space complexity for non prefix-valid parsers is $O(n^4)$.

2 Tree Adjoining Grammars

A Tree Adjoining Grammar [TAG] (Joshi, 1987) is given by a set of *elementary trees* partitioned into *initial trees* and *auxiliary trees*. A node ν is labeled by l_ν , which is a non-terminal for internal nodes and a terminal or a non-terminal for leaves. Each auxiliary tree β has a distinguished leaf, called its *foot* and labeled by a non-terminal, the same as the root node of β .

Figure 1: Adjunction

Two operations may be used to derive trees from elementary trees. The first one, called *substitution*, replaces a leaf node labeled by a non-terminal A by an initial tree α whose root is also labeled by A . The second operation, called *adjunction*, is illustrated by Figure 1. An auxiliary tree β whose root is labeled by A may be adjoined at any node ν labeled by A . The subtree rooted at ν (and noted t_ν) is grafted to the foot of β . Adjunctions occurring on a spine lead to nested adjunction.

Feature TAGs extend TAGs by attaching to nodes a pair of *top* and *bottom* arguments, represented by first-order terms.

3 Describing parsing strategies with 2SAs

Parsing TAGs may be viewed as traversing elementary trees from left to right² with suspensions occurring on substitution and adjunction nodes.

²Of course, other kinds of traversal are possible, such as right to left or bidirectional ones.

As illustrated in Figure 2, we associate to each node ν the following information, in order to describe a top-down prefix-valid³ left-to-right parsing strategy :

- left and right *position variables* $\bullet P_\nu$ and $P_\nu \bullet$ (resp. $\bullet P_\nu$ and $P_\nu \bullet$) delimiting the span of ν , possibly with adjunction (resp. without adjunction). When no adjunction is done on ν , we will have to ensure that $\bullet P_\nu = \bullet P_\nu$ and $P_\nu \bullet = P_\nu \bullet$.
- *dotted nodes* $\bullet \nu$ and $\nu \bullet$ (resp. $\bullet \nu$ and $\nu \bullet$) denoting *computation points* associated to entering and exiting ν , possibly with adjunction (resp. without adjunction). As shown in Figure 2, each dotted node is implicitly associated to a position variable.
- *call and return terms* $\bullet T_\nu = l_\nu(\bullet P_\nu)$ and $T_\nu \bullet = \text{ret}(P_\nu \bullet)$ (resp. $\bullet B_\nu = l_\nu(\bullet P_\nu)$ and $B_\nu \bullet = \text{ret}(P_\nu \bullet)$) used as pieces of information when starting or resuming a suspension for the node, possibly with adjunction (resp. without adjunction).⁴

Note that there are many implicit congruences between positions variables and dotted nodes. For instance, for a node μ visited just after ν , we have $\nu \bullet \equiv \bullet \mu$ and $P_\nu \bullet \equiv \bullet P_\mu$.

Figure 2: Some notations for TAGs

In order to simplify notation and because the case of adjunction will come again and again, we also omit most subscripts when possible, assuming the following equalities (for a successful adjunction of

auxiliary tree β at node ν).

$$\begin{aligned} \bullet T &\equiv \bullet T_\nu \equiv \bullet T_{r_\beta} & T \bullet &\equiv T_\nu \bullet \equiv T_{r_\beta} \bullet \\ \bullet B &\equiv \bullet B_\nu \equiv \bullet B_{f_\beta} & B \bullet &\equiv B_\nu \bullet \equiv B_{f_\beta} \bullet \end{aligned}$$

Intuitively, when reaching the entry point $\bullet \nu$ with left position $\bullet P_\nu$ and deciding to perform an adjunction, the current traversal is suspended and the call information $\bullet T_\nu$ is used to fetch some auxiliary tree β and to start its traversal. When reaching foot f_β , the traversal of β is suspended and $\bullet \nu$ is resumed and leads to $\bullet \nu$ at position $\bullet P_\nu$. When reaching $\nu \bullet$ at position $P_\nu \bullet$ (denoting the recognition of ν without adjunction), a new suspension occurs and the traversal of β is resumed on the left of its spine. When the traversal of β is finished, $\nu \bullet$ is resumed and leads to $\nu \bullet$ at position $P_\nu \bullet$ (denoting the recognition of ν with adjunction).

As illustrated by Figure 3, these various steps may naturally be described using two stacks, a master stack **MS** used to record the tree traversals and an auxiliary stack **AS** used to keep the information needed to resume suspensions due to adjunctions. We have chosen to take $\bar{\nu} = \nu$ (the name of the node) and $\underline{\nu} = \perp$ (the null information) as pieces of information recorded on **AS**, but other choices are possible for other parsing strategies.⁵ In Figure 3, we also use *composite* stack elements of the form $\bullet B_\nu + \bar{\nu}$ (transition **FCALL**) to compose information relative to a node ($\bullet B_\nu \equiv \bullet B_{f_\beta}$ for the footnode f_β) and information relative to an adjunction ($\bar{\nu}$ for the adjunction node ν).

More formally, the parsing steps may be expressed as transitions of a 2-stack automaton (Becker, 1994; Villemonte de la Clergerie and Alonso Pardo, 1998). A transition τ of the form $(\Xi, \xi) \mapsto (\Theta, \theta)$ applies on any *configuration* $(\mathbf{MS}, \mathbf{AS}) = (\Psi \Xi, \psi \xi)$ and returns $(\Psi \Theta, \psi \theta)$. Some of the steps of the parsing strategies are explicited by the following transitions, with X, Y denoting free variables, instantiated by matching during transition application.⁶

ACALL	$(\bullet \nu, \epsilon) \mapsto (\bullet \nu \bullet T_\nu, \bar{\nu})$
ARET	$(\bullet \nu T_\nu \bullet, \underline{\nu}) \mapsto (\nu \bullet, \epsilon)$
ASEL	$(\bullet T_r, \epsilon) \mapsto (\bullet r, \epsilon)$
APUB	$(r \bullet, \epsilon) \mapsto (T_r \bullet, \epsilon)$
FCALL	$(\bullet f, X) \mapsto (\bullet f (\bullet B_f + X), \epsilon)$
FRET	$(\bullet f (B_{f_\bullet} + Y), \epsilon) \mapsto (f_\bullet, Y)$
FSEL	$(\bullet B_\nu + \bar{\nu}, \epsilon) \mapsto (\bullet \nu, \epsilon)$
FPUB	$(\nu \bullet, \epsilon) \mapsto ((B_{\nu_\bullet} + \underline{\nu}), \epsilon)$

⁵For instance, we may handle adjunctions in a bottom-up way by taking $\bar{\nu} = \perp$ and $\underline{\nu} = \nu$.

⁶Actually, the basic model of 2SA uses symbols as stack elements and explicits the propagation of the position variables as well as of other pieces of information. An extended model uses terms as stack elements and uses unification to apply transitions and handle position variables and features. We are using this extended model but have decided to skip details in this presentation for sake of clarity and because they are not essential to the discussion.

³By *prefix-valid* we mean that failure in an alternative is detected as soon as a parsed prefix of the input string has no way to be completed by some string into a valid parse.

⁴These terms arise from the modulated Call/Return model (Alonso Pardo et al., 2000). Other values are possible for other parsing strategies, in particular when dealing with Feature TAGs.

Figure 3: Illustration of some steps

In practice, the transitions may be grouped in *meta-transitions* by (a) grouping pairs of related call and return transitions such as **ACALL** and **ARET** and (b) considering dotted nodes such as $\nu^\bullet$ as *continuations*. For instance, figure 4 shows the skeleton of a meta-transition representing the traversal of an auxiliary tree with root r and some adjointable node ν .⁷

The typed feature-structure representation of the meta-transitions has no special signification, except that it closely corresponds to the internal representation used by our compiler. Meta-transitions are important for the rest of the paper, because they explicit some particularities of TAGs (and of the parsing strategy).

There is one meta-transition per tree, possibly including disjunctive values to handle non mandatory adjunction nodes. Actually, it is theoretically possible to merge into some disjunctive meta-transition the traversal of several trees.⁸

4 Strong DP interpretation

The strong Dynamic Programming interpretation of 2SAs is based on the identification of elementary 2SA derivations that may be reused and that may be represented by *items*. Application rules are provided to combine together items and transitions in order to retrieve all possible 2SA derivations. We just introduce minimal background about the interpretation and readers are invited to consult (Villemonde de la Clergerie and Alonso Pardo, 1998; Alonso Pardo et al., 2000).

The interpretation considers two kinds of items, namely Context-Free [CF] Items $A/B/C$ (also represented by $A/B/[\diamond]C$) and Escaped Context-

Free [xCF] Items $A/B/[DE]C$ representing sub-derivations passing by configurations $\mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{D}$ and $\mathcal{E}$.⁹ The items keep only projections of the configurations, and the less information is kept, the better computation sharing will potentially be. Practically, for a configuration $\mathcal{X} = (\exists X, \xi x)$, only the topmost elements X and x of each stack need to be kept in a *mini configuration* $\langle X, x \rangle$ or a *micro configuration* $\langle X \rangle$. One can further reduce the amount of information by keeping for X only the “triggering” fraction of information $\epsilon(X)$ that is consulted to start some computation above X (on the stack MS).

dotted node X	$\bullet\nu$	$\bullet\nu$	$\nu\bullet$	$\nu^\bullet$
$\epsilon(X)$	$\bullet T_\nu$	$\bullet B_\nu$	$B_\nu\bullet$	$T_\nu^\bullet$

Finally, for TAGs, Table 1 displays the patterns for the various items related to an adjunction on node ν in a tree rooted at r . If ν dominates some foot g in an adjunction on μ , $[DE] = [\langle \bullet B_g, a \rangle \langle B_g\bullet + b \rangle]$ and $(a, b) = (\bar{\mu}, \underline{\mu})$; otherwise $[DE] = [\diamond]$ and $(a, b) = (\diamond, \diamond)$.

There are several generic rules used to combine items and transitions, some of them being rather complex. More precisely, when parsing TAGs, the most complex case corresponds to returning from a fully recognized auxiliary tree β to the adjunction node ν . In first approximation, this step requires combining three items (start of the adjunction, recognition of the subtree t_ν and recognition of β) with a transition **ARET**. However, a straightforward application does not ensure an optimal worst-case time complexity in $O(n^6)$ and this step is actually split into the rules of Figure 5, with the introduction of an intermediary structure with superscript L .

Furthermore, still to ensure optimal worst-case complexity, projections of items have to be considered with some components removed (marked by $\star$)

⁷Actually, we have considered the case of a mandatory adjunction at ν . To handle non mandatory ones, we add disjunction points in the meta-transitions and share common continuations between alternatives.

⁸There are relationships to investigate between the meta-transitions and the finite-state automata used in (Evans and Weir, 1998; Carroll et al., 1998).

⁹The diverse conditions satisfied by these configurations are outside the scope of this paper.

Figure 4: Sketch of a meta-transition for an auxiliary tree [strong interpretation]

	after CALL	before RET
on ADJ ν	$\langle \bullet T \rangle / \langle \bullet T \rangle / \langle \bullet T, \bar{\nu} \rangle$	$\langle \bullet T \rangle / \langle \bullet T \rangle / [\langle \bullet B, \bar{\nu} \rangle \langle B_{\bullet} + \nu \rangle] \langle T^{\bullet}, \nu \rangle$
on FOOT f	$\langle \bullet T_r \rangle / \langle \bullet B, \bar{\nu} \rangle / \langle \bullet B + \bar{\nu}, a \rangle$	$\langle \bullet T_r \rangle / \langle \bullet B, \bar{\nu} \rangle / [DE] \langle B_{\bullet} + \nu, b \rangle$

Table 1: Items at adjunction and foot nodes [strong interpretation]

in the rules. In particular, three projections are needed for the recognition of t_{ν} , the subtree rooted at ν , in the context of an adjunction on ν .

For TAGs, these remarks lead to the execution model illustrated in Figure 6, obviously complex to decrypt¹⁰ and implement. This model also incorporates the notions of *partial applications* and *immediate applications*.

Partial applications decompose a complex application rule into a cascade of elementary applications, which combine only an item and a transition or some intermediary object (close to a transition). Immediate application is a (partial) application done as soon as a dotted node X is reached, in order to avoid tabulating an item relative to X .

Immediate application is made possible because the transitions have been grouped into meta-transitions. For instance, when reaching an adjunction node ν with dotted computation point $\bullet\nu$, one can immediately install:

- an item CAI to fetch and start the recognition of some auxiliary tree.
- an intermediary transition CFI $>$ preparing the recognition of the subtree t_{ν} rooted at ν .
- a projection item I_a preparing the return from t_{ν} to the auxiliary tree.
- an intermediary transition RAI $>$ preparing the return from the auxiliary tree to the adjunction node.

¹⁰To help the reading, object names follow the model Call/Return Aux/Foot (Item or transition $I >$) plus indices for projections (1, 2, 3, ...) and intermediary objects (a, b, c ...), giving for instance CAI, RFI_b, RFI $>_1$, ...

Looking at Figure 6, we observe the three projections RFI_{a,b,c} needed to record the recognition of subtree t_{ν} and the two complex cascades of (partial) applications required to return to the auxiliary tree and to the adjunction node.

5 Weak DP interpretation

The strong DP interpretation derives from a generic view of 2SAs, independently from TAGs. Efforts have been made to ensure an optimal worst-case complexity but they lead to a complex model. Furthermore, it is not proven that these efforts are worthwhile in practice.

Therefore, we tried to exploit the properties of TAGs to simplify the strong DP interpretation into two directions:

1. Removing more information from items.
2. Relaxing tabulation, possibly increasing worst-case complexity, but still ensuring polynomial worst-case complexity.

To remove information, we can note that parsing an auxiliary tree β does not depend on the node ν that started the adjunction. The only pertinent information (needed at the root and foot nodes) is given by $\bullet T$, $T^{\bullet}$, $\bullet B$, and $B_{\bullet}$. The node name ν is needed only when leaving the foot node to parse the subtree t_{ν} rooted at ν . But for TAGs, the meta-transition indicates, as soon as $\bullet\nu$ is reached, the continuation $\bullet\nu$ to follow. By immediate application, one can prepare an intermediary transition waiting for a compatible foot node to be reached. Practically, this idea means that $\bar{\nu}$ and ν may be removed and that we can use micro configurations $\langle X \rangle$

$$\begin{array}{l}
(dxCF) \quad \frac{\star / \langle \bullet B, \bar{\nu} \rangle / [DE] \langle B_{\bullet} + \underline{\nu}, \star \rangle^{RFI_b} \quad \langle \bullet T \rangle / \langle \bullet T \rangle / [\langle \bullet B, a \rangle \langle B_{\bullet} + \underline{\nu} \rangle] \langle T \bullet \rangle^{RAI}}{\langle \bullet T \rangle \langle \bullet T \rangle [[DE]] \langle T \bullet \rangle^L} \\
\\
(ARET) \quad \frac{(\bullet \nu T^{\bullet}, \underline{\nu}) \mapsto (\nu^{\bullet}, \epsilon) \quad \frac{\langle \bullet T_r \rangle / N / \langle \bullet \nu, a \rangle^I \quad \langle \bullet T_r \rangle / \star / [DE] \langle \star, b \rangle^{RFI_c} \quad \langle \bullet T \rangle \langle \bullet T \rangle [[DE]] \langle T^{\bullet}, \underline{\nu} \rangle^L}{\langle \bullet T_r \rangle / N / [DE] \langle \nu^{\bullet}, b \rangle}}{D = \langle \bullet B_r, a \rangle}
\end{array}$$

Figure 5: Some application rules [strong interpretation]

Figure 6: Cascades of partial evaluations related to an adjunction [strong interpretation]

in place of mini ones $\langle X, x \rangle$. We can also simplify composite terms $X + x$ into X .

Tabulation may be relaxed by changing the way the subtree t_ν is traversed. The strong DP interpretation traverses t_ν independently of the adjunctions that have been started (but not yet finished) for nodes on the path π_ν from ν to the root of α (if ν belongs to α), hence allowing to share the traversal of t_ν for different adjunctions on ν starting at the same position but occurring in different contexts. In a way, the strong DP interpretation does not consider t_ν as a subtree of α but rather as a tree of its own. We decided to relax this condition by requiring that the traversal of t_ν be done in the context of a larger traversal of α , including in particular the ongoing adjunctions on π_ν .

Here again, this choice is possible because, when reaching dotted node $\nu_\bullet$ at the end of t_ν , we know of course that we must suspend the computation (to finish traversing β) but also that, when resuming

the computation, we can directly jump to $\nu^\bullet$. This difference of point of view leads to a revised version of meta-transitions, as illustrated by Figure 7 where $\nu^\bullet$ is now seen as the next continuation of $\nu_\bullet$ (to be compared with Figure 4 for dotted nodes $\bullet \nu$, and $\nu_\bullet$). The new meta-transition does not correspond to a set of new transitions but rather to a different organization of the original set.

Applying these various ideas leads to CF items $A/N/C$ and xCF items $A/N/[DE]C$, where N denotes a stack of pairs $\langle \bullet T_\mu \rangle \langle \bullet B_\mu \rangle$. We can show that $A = \langle \bullet T_r \rangle$ where r is the root of some elementary tree α and C is some dotted node or information relative to a node ν of α . The micro configuration $\langle \bullet T_\mu \rangle$ records starting an adjunction at μ and leaving α while $\langle \bullet B_\mu \rangle$ records leaving a foot node and coming back to α . Therefore, an item records the list of all adjunctions that are still under completion on π_ν for some node ν and tree α . Table 2 displays

	after CALL	before RET
on ADJ ν	$\langle \bullet T \rangle // \langle \bullet T \rangle$	$\langle \bullet T \rangle // [\langle \bullet B \rangle \langle B \bullet \rangle] \langle T \bullet \rangle$
on FOOT f	$\langle \bullet T_r \rangle / N \langle \bullet T \rangle \langle \bullet B \rangle / \langle \bullet B \rangle$	$\langle \bullet T_r \rangle / N \langle \bullet T \rangle \langle \bullet B \rangle / [DE] \langle B \bullet \rangle$

Table 2: Items at adjunction and foot nodes [weak interpretation]

$$\begin{array}{ll}
(\text{ACALL}) & \frac{(\bullet \nu, \epsilon) \mapsto (\bullet \nu \bullet T, \bullet \nu) \quad A / \star / \langle \bullet \nu \rangle^I}{\langle \bullet T \rangle // \langle \bullet T \rangle^{\text{CAI}}} \\
(\text{FCALL}) & \frac{(\bullet f, \bullet \nu) \mapsto (\bullet f \bullet \nu, \epsilon) \quad A / N / \langle \bullet \nu \rangle^I \quad \langle \bullet T \rangle / \star / \langle \bullet B \rangle^{CFI}}{A / N \langle \bullet T \rangle \langle \bullet B \rangle / \langle \bullet \nu \rangle} \quad \text{CFI} \geq I + \text{FCALL} \\
(\text{FRET}) & \frac{(\bullet f \bullet \nu \bullet, \epsilon) \mapsto (f \bullet, \nu \bullet) \quad \langle \bullet T \rangle / O / \langle \bullet f \rangle^J \quad \star / \star \langle \bullet T \rangle \langle \bullet B \rangle / [\star \star] \langle B \bullet \rangle^{\text{RFI}}}{\langle \bullet T \rangle / O / [\langle \bullet B \rangle \langle B \bullet \rangle] \langle f \bullet \rangle} \quad \text{RFI} \geq J + \text{FRET} \\
(\text{ARET}) & \frac{(\bullet \nu T \bullet, \nu \bullet) \mapsto (\nu \bullet, \epsilon) \quad A / N \langle \bullet T \rangle \langle \bullet B \rangle / [DE] \langle \nu \bullet \rangle^K \quad \langle \bullet T \rangle // [\langle \bullet B \rangle \langle B \bullet \rangle] \langle T \bullet \rangle^{\text{RAI}}}{A / N / [DE] \langle \nu \bullet \rangle} \quad \text{RAI} \geq K + \text{ARET}
\end{array}$$

Figure 8: Some application rules [weak interpretation]

We have also tried the parsers on “pathological” sentences, keeping the same grammar. We have considered 4 kinds of recursive constructions indexed by some integer n and used them to build larger and larger sentences (and getting more and more ambiguities). Table 4 shows that the weak interpretation remains faster than the strong one (and it holds true for all the values of n that we have tried).

sentence	Strong		Weak	
	TD	Hyb.	TD	Hyb.
(... of) 10	6337	5362	1560	1449
(who ...) 9	66138	44359	13722	11808
(who ...) 5 (... of) 5	25070	16922	5298	4173
(who ... (... of) 3) 3	43313	34602	9283	8448

Table 4: Results (in ms) for “pathological” sentences

Of course, we are aware that some “pathological” grammars may give better results with the strong interpretation. For example, for the grammar of Figure 10 which generate language a^* , we get the results of Figure 11. Now the question is to know if linguistic grammars and sentences exhibit this kind of behaviour.

7 Conclusion

We have presented a new Dynamic Programming interpretation of 2SAs specialized to build simple and efficient tabular parsers for TAGs. The preliminary experiments done on a small but realistic linguistic grammar have justified the interest of our approach, even if the optimal worst-case complexity is not en-

Figure 10: Pathological grammar

Figure 11: Results for the “pathological” grammar

sured w.r.t. the length of the input string. Of course, more experiments remain to be conducted on a wider range of grammars.

Beside efficiency, the other advantages of our interpretation are its simplicity and the predominance of the notion of continuation. We feel that these ideas could be fruitful in order to design simple tabular parsers satisfying the valid prefix property for other formalisms than TAGs and still running in polynomial time (for instance for *mildly context-sensitive* formalisms or *Linear Context Free Rewrit-*

Sentence	Strong		Weak	
	TD	Hyb.	TD	Hyb
$\emptyset$	443	428	250	253
Jean aime Marie	745	470	124	73
Yves montre des fleurs à Sharon	1494	798	169	97
Kathy regarde un livre avec Stéphane	1057	805	157	99
un ami américain de Yves qui visite la France boit du bon vin	2440	1594	427	299
la jolie fille pense que Andrew est le grand ami de son chien	1679	1249	274	167
Marie comprend que Kathy dort bien chez Andrew	1326	1011	241	117
Anne voit les fleurs que Yves cherche sur la table	1851	1322	278	186
Jean pense que Béatrice perd les pédales	1396	1012	221	130
le petit chat de Sabine court vite	962	721	183	106
Andrew court parfois les filles	856	674	130	80
la fille de Marie aime bien les fleurs	1179	896	183	103
qui est Bonnie	832	529	117	79
qui dit que Yves a un chien	1215	910	188	112
un enfant intelligent de Marie comprend lentement que sa mère est bête	2140	1349	330	200

Table 3: Results (in ms)

ing Systems). In particular, reasoning in terms of continuations and suspensions seems interesting when parsing interleaved constituents (even if the pattern of suspensions is more complex than the one used for TAGs).

It is also interesting to note (once again) that tabulation and parsing strategies are (largely) orthogonal issues: for a parsing strategy expressed by a set of 2SA transitions, we have at least two ways to interpret it using tabulation. Beside the original “strong” interpretation and our “weak” one, there actually exists a whole range of intermediary interpretations corresponding to different levels of tabulation. For instance, by increasing tabulation and using items of the form $A/\langle \bullet T \rangle \langle \bullet B \rangle / [DE] \langle \nu \bullet \rangle$, the weak DP interpretation becomes very similar to the Earley prefix-valid algorithm of (Schabes, 1991), with time complexity $O(n^9)$ and space complexity $O(n^6)$. Again, increasing tabulation and using items $A/\langle \bullet B \rangle / [DE] \langle \nu \bullet \rangle$ leads to a DP interpretation close to the strong one but without keeping information relative to the Auxiliary Stack **AS** in the items. The strong DP interpretation may also be relaxed by not using some projections or the intermediary object L (Figure 5). There is also the possibility not to check subsumption on some objects. Some of these possibilities should be investigated, noting that, with some care, several of them can be made to coexist in a single parser.

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