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# Generating Grammatical and Lexical Anaphora in Assembly Instructional Texts

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**Abstract.** In this paper, we discuss the problem of generating natural anaphora in assembly instructional texts. We first present a detailed account of grammatical and lexical anaphora and we examine a set of constraints for selecting these devices. As language is often redundant and an optimal referring expression is computationally prohibitive, we take the view that the generation of anaphora should be based on a thorough linguistic study and should lead to a natural choice, rather than an optimal one. We then present a text generation system built to evaluate the linguistic constraints. This component takes as input a specification of the sequence of actions to be performed in a cooking recipe and selects and produces the most appropriate anaphoric device to be used in the text.

## 1 Introduction

In this paper, we propose a process for generating "natural" **grammatical and lexical anaphora** in French texts dealing with assembly tasks, taking into account local and global focus as well as lexico-semantic constraints [Tut92]. Lexical anaphora is a very common phenomenon in any text; however, most studies on anaphora in text generation have only considered grammatical anaphora (e.g., pronouns). Moreover, past treatments of lexical anaphora (e.g., superordinates), rely mainly on conceptual taxonomic considerations [Dal92, Rei90, Gra84], whereas we believe that lexical anaphora rules must be grounded in a detailed lexical semantic description of the textual genre.

We take the view that the generation of anaphora should lead to a natural choice rather than an optimal one; and this, for two reasons. First, in a linguistically motivated work, the study of anaphora usage is more accurate when dealing with natural texts (which do not aim for optimality even in very utilitarian texts like instructions). Second, as shown by Reiter and Dale [RD92], the computational complexity of generating optimal (minimally distinguishing) NPs is prohibitive.

Overall, our work complements well Reiter and Dale's work [RD92]. The "natural" approach is shared by both research projects, but the anaphoric devices studied are different. In addition to grammatical anaphora, our work considers a wide range of lexical devices; while Reiter and Dale's work emphasizes *distinguishing descriptions* (what we call here partial repetitions).

In this paper, we first present the kinds of anaphora we have studied present in assembly instructional texts. The constraints underlying their production are then explained. Finally, we show how these constraints have been implemented to automatically generate the anaphora found in cooking recipes.

## 2 Anaphora in Assembly Instructional Texts

### 2.1 Kinds of Anaphora

A textual element $T$ is an *anaphora* of an antecedent $A$ (previously introduced in the text) if its referential interpretation depends on the interpretation of $A$. To generate any anaphoric link (i.e., instance of anaphora), the previous context of the anaphora should thus be taken into account. We speak of anaphora in terms of the process by which the anaphoric expression can be derived from the antecedent form (e.g., "partial repetition"), even though we envision a generation model which derives linguistic forms from conceptual representations under conceptual and linguistic constraints.

Following Halliday and Hasan [HH76], two main classes of anaphora can be distinguished:

**Grammatical anaphora** uses lexemes which belong to a closed class (e.g. pronoun, definite article, demonstrative adjective) or no linguistic mark at all (in the case of ellipsis).

**Lexical anaphora** uses lexemes which belong to an open lexical class (adjective, noun, verb or adverb). The anaphora and its antecedent typically share meaning components. For example, *flower* can be used as a lexical anaphora (hyperonym) for *rose*.

Our study is restricted to coreferential anaphora, i.e. devices for which the antecedent has the same referent as the anaphoric expression. Tables 1 and 2 show the types of anaphora examined in our study.

### 2.2 Assembly Instructional as a Textual Genre

The research is focused on assembly instructional texts, taking the particular case of cooking recipes. Using a corpus of naturally occurring assembly texts prevented us from oversimplifying linguistic phenomena and enabled us to formulate algorithms which give a faithful account of anaphora encountered in natural texts. Nevertheless, we believe that a large part of the linguistic study

| Grammatical Anaphora | Definition | Example |
|---|---|---|
| Pronominalization | Replacement of an NP by a personal pronoun. | {carottes, poireaux, tomates} → les<br>{*carrots, leeks, tomatoes*} → *them* |
| Ellipsis | Replacement of an NP or a set of NPs by nothing. | {carottes, poireaux, tomates} → Ø<br>{*carrots, leeks, tomatoes*} → Ø |
| Coreferential Definite NP | Replacement of an indefinite NP or set of NPs by a Definite NP (see table 2). | |

**Table 1.** Grammatical Anaphora Studied

reported here can be generalized to other domains. In particular, we hypothesize that, while grammatical constraints, relying on discourse structure and focalization, vary a great deal according to the textual genre, the conceptual and lexical constraints governing lexical anaphora are generalizable to other genres. The anaphoric lexical devices presented here for recipes constitute only a subset of those that could appear in the language as a whole. While a textual genre might use only a subset of possible lexical anaphoric devices, these devices are governed by the same constraints in any genre. For example, typical result mentions (eg. *mix* → *mixture*) is widespread in instructional texts but the constraints governing them are the same in any genre.

Assembly instructional texts can be characterized by a sequence of instructions for building a new object from other objects. This genre is primarly aimed at ordering the reader to perform some task; thus its rhetorical/intentional structure need not be taken into account when selecting an anaphora. This of course is not the case when narrative genres are considered. Assembly instructional texts have already been studied in computational linguistics and artificial intelligence (both dialogues [Gro77, App85], and monologues [Ham89, Dal92]). Cooking recipes represent an easily accessible variety.

A thorough study of 63 recipes[3] (16,300 words) showed that some grammatical anaphoric devices are particular to this genre. For example, ellipsis of verbal complement (as in (1)) is the most common anaphoric device while it is relatively rare in written standard (non-instructional) language[4]:

(1) Mélanger les carottes, les pommes de terre et le beurre. Saler Ø[5].
*Mix the carrots, the potatoes and the butter. Sprinkle Ø with salt.*

[3] different versions of nine traditional French recipes
[4] Object ellipsis is quite common in dialogues.
[5] The symbol Ø denotes ellipsis.

Ellipsis obeys many constraints, some of them radically different in French from those governing pronominalization:

- The surface antecedent of an ellipsis may be quite distant, even in a previous paragraph, quite unlike the case for pronouns, which are never far from their antecedents in instructions [vDK83].
- Pronouns are preferably produced to lexicalize sets of similar objects, i.e. objects having a close common superordinate. Actually, as we will see below, pronouns are more sensitive to local focus constraints, while ellipsis are more sensitive to global focus constraints.

Another interesting aspect of assembly instructional texts is that pronominalization appears hampered by the fact that objects in some instructional domains change state. For example, in (1) we can refer back to the previous objects with a typical result noun like *mixture* or with an ellipsis, while the personal pronoun *them* seems inappropriate because the three initial objects have changed state. This problem can be generalized to any assembly text.

In recipes, pronominalization is rather simplified. As clauses are very short, ambiguity is not as strong as it could be in narrative texts. On the other hand, while vocabulary is quite varied, we encounter many different lexical anaphora, probably more than in most technical texts.

## 3 Conditions Constraining the Production of Anaphora

In this section, we will present a set of constraints governing anaphora in assembly instructional texts. For the sake of generalization, we will try to establish to what extent the constraints examined are specific to the sublanguage.

A coreferential anaphora is produced when an object already introduced in the text must be lexicalized. The lexical choice for a coreferential anaphora is a two-stage process:

1. A first choice is made between grammatical anaphoric devices, i.e. between ellipsis, pronominalization and definite noun phrase (see table 1).
2. Then, if a definite noun phrase is chosen, a lexical anaphora (see table 2) is selected.

To select the most appropriate anaphora, several constraints must be taken into account: non-ambiguity, focus, distance, lexico-grammar, lexico-semantics, and conceptual constraints.

### 3.1 Non-Ambiguity Constraints

Of course, an anaphora can only be chosen if it designates in a non-ambiguous way the intended referent. Checking ambiguities differs according to the *ambiguity domain* of the anaphora-to-be. For example, while a pronoun can only be

ambiguous with relation to the antecedents of the previous clause, ambiguity for ellipsis does not need to be checked because this anaphoric device is only allowed when it refers to the global focus. Non-ambiguity constraints appear to us more determining than brevity constraints (see [Dal92] and [Rei90] for a discussion about minimal distinguishing description). Studying our corpus thoroughly, we noticed cases of redundancy, apparently used to refresh the hearer's memory about relevant attributes, especially in long texts.

### 3.2 Focus Constraints

It is well-known that the local focus is a determining factor for pronominalization ([Sid81, GAW83]). Rules exhibited by Dale [Dal92] in English for generating pronouns in recipes cannot be transposed into French. For Dale, an obligatory element which refers back to the center (a verb complement may be obligatory, depending on the verb), can be lexicalized as a pronoun. The center is defined as the result of the previous action. These findings do not agree with the following French examples.

(2) a. Mélanger les carottes, les pommes de terre et le beurre.
b. ?* Les saler.
c. Saler Ø.
*Mix the carrots, the potatoes and the butter.*
*Sprinkle them with salt.*
*Sprinkle Ø with salt.*

(3) a. Couper les carottes en rondelles.
b. Les saler.
c. Saler Ø.
*Cut the carrots in slices*
*Sprinkle them with salt.*
*Sprinkle Ø with salt.*

- While the set {*carrots, potatoes, butter*} fills the center in (2a), it cannot easily be coreferential with a pronoun; in (3), {*carrots*} fills the center and can be coreferential either with a pronoun or with an ellipsis.
- The obligatory nature of the verb complement does not seem important, because *saler* accepts both ellipsis and personal pronoun. To cope with personal pronoun generation, we had to define the concept of local focus as the element the action is about. In recipes, the element in local focus is generally in the direct object syntactic function. An element, be it a set or a single element, will be pronominalized if it is the local focus of the previous clause. If not, all non-ambiguity constraints need to be checked. This includes checking for morphological and semantic ambiguities. This algorithm enables us to generate the following example:

  (4) Faire chauffer la moitié du beurre. *Y* mettre l'échalote hachée. *La* faire blondir.

*Melt half of the butter in a pan. Add minced scallion [to it]. Heat [it] until yellow.*

where *la* refers back to the local focus of the previous clause, *l'échalote*. Although this pronoun may be ambiguous in relation with its gender and number (possible ambiguity with *moitié*), it is not ambiguous because its antecedent is the local focus of the previous clause.

We found that ellipsis could not be explained by a verb property, but in relation to the global focus, this being defined as the stack of the most salient previous local foci in relation to discourse segments. In recipes, our ad hoc definition of saliency is the following: salient objects are main ingredients, while seasonings and instruments are less salient. Contrary to the focus space management proposed by Grosz and Sidner in [GS86], we found that the elements contained in the ellipsis could refer to the elements contained in the previous sub-recipes. We thus include in the global focus stack the most salient local foci belonging to the previous discourse segments. We believe that this global focus management is specific to the procedural nature of assembly instructional texts.

Focus constraints do not pertain to lexical anaphora except for typical result mention.

We believe that the local focus definition is strongly tied to the textual genre; as defined here, it is obviously too specific to be applied to other textual genres.

In assembly instructional texts, global focus cannot be only defined in structural terms. It seems to depend as much on extralinguistic knowledge (in recipes, things are added and mixed) as on textual structures.

### 3.3 Distance Constraints

Pronominalization is very simplified in procedural texts. The antecedent, be it realized in surface or not (as an ellipsis), is always in the previous clause, and almost never in the previous paragraph. Long distance pronominalization does not occur. For ellipsis, distance is not really relevant, because, as seen above, global focus constraints are more important. Finally, for most lexical anaphoric devices, except typical result mention, distance does not seem to play an important role.

Nevertheless, let us emphasize here that, as is often the case in text generation, we only studied very short texts (four or five paragraphs). While the ambiguity domain seems rather limited for grammatical anaphora, it is probably not the case for lexical anaphora. How the hearer's memory needs to be refreshed about referents (how distance constraints vary according to the textual genre, discourse structure and rhetorical structure) is a very interesting topic that text generation should look into.

### 3.4 Lexico-Grammatical Constraints

In text generation, one encounters the problem of linguistic availability as some linguistic items simply do not exist for a given grammatical function. Thus, the

ellipsis cannot be the grammatical subject, while it can fill almost every post-verbal complement (nominal) function. Also, some prepositional phrases cannot be filled with pronouns, in particular when dealing with inanimate antecedents. For example, PPs introduced with *avec* (with) cannot naturally introduce inanimate pronouns.

(5) Annie m'a offert un superbe stylo-plume pour mon anniversaire et j'adore écrire avec (*? lui/ ? ∅).
*Annie offered me a beautiful fountain pen and I love to write with it.*

The pronoun is not very natural and the ellipsis conveys a colloquial tonality that is not necessarily desirable. When the pronoun replaces a noun complement introduced by *de*, a possessive adjective should be produced for human referents instead of pronouns, but for inanimate referents, this is not often possible, and pronominalization is replaced by ellipsis. Compare for example:

(6) a. Cook the duck. Remove *its wings.
b. Do you know that guy? His car is a real old Dodge.

Lexico-grammatical constraints obviously do not vary according to the textual genre.

### 3.5 Lexico-Semantic Constraints

To generate natural lexical anaphora, we require a well-developed lexico-semantic model. The lexical part of the Meaning-Text Model [MP87], and in particular Lexical Functions (LF) enables one to systematize lexico-semantic relations to create direct and indirect coreferential relations between lexical items [TK92]. If a lexical gap occurs in text generation, LF compositions can also be used to create a lexical link. For example, let us suppose that after having introduced the following sentence,

(7) Laisser étuver la viande.
*Let the meat steam.*

we have to refer back to the action *la viande étuve*. We could try to use a nominalization ($S_0$ in the $FL$ notation). But, as there is no nominalization for the verb *étuver*, we could use instead the nominalization of the generic term, $S_0(Gener(étuver)) = cuisson$. We could thus produce the following sentence:

(8) À la fin de la cuisson, ajouter les épices.
*At the end of cooking, add the spices.*

Moreover, it seems that the term introduced should not only be discriminating, but natural, as has been emphasized by Reiter [Rei90], taking as a basis not only conceptual considerations, but also lexical use and lexical semantic considerations. For example, we notice that superordinate terms can often be more easily used to lexicalize reference to a non-homogeneous set of elements than for reference to a single element or homogeneous set, as illustrated in (9) and (10).

(9) Mettre les carottes dans de l'eau bouillante.
? Enlever les légumes après 10 minutes.
*Put the carrots into boiling water.*
*Remove the vegetables after 10 minutes.*

(10) Mettre les carottes, les poireaux et les pommes de terre dans de l'eau bouillante.
Enlever les légumes après 10 minutes.
*Put the carrots, the leaks and the potatoes into boiling water.*
*Remove the vegetables after 10 minutes.*

However, the ease with which a superordinate term can be used depends on the particular noun. For example, in French, *viande* (meat) can be substituted for *bœuf* even in singular:

(11) Mettre le bœuf à cuire dans l'eau bouillante.
Retirer la viande au bout de 20 minutes.
*Put the beef into the boiling water.*
*Remove the meat after 20 minutes.*

This somewhat surprising phenomenon can be analyzed using the notion of basic level object proposed by Rosch et al. [RMW+76]. They demonstrated that the taxonomy of concepts could be organized using a structure with three levels: superordinate, basic and subordinate. They define the basic level as follows:

> "basic objects are the most inclusive categories whose members: (a) possess significant numbers of attributes in common, (b) have motor programs which are similar to one another, (c) have similar shapes, and (d) can be identified from averaged shapes of members of the class" (p. 382).

It has been shown that lexemes corresponding to basic level objects seem to be the most natural terms to introduce referents already identified. For example, if one wants to refer to some *champignons de Paris* (button mushrooms), one would prefer to call them *champignons* (mushrooms), provided that there is no potential ambiguity with any other mushrooms. *Champignons de Paris* would seem too specific in this context and *légumes* (vegetables) would seem too vague. This choice is not made randomly: *champignon* is the highest basic level concept to designate these objects. This would explain why in (11), on can refer to *bœuf* with the superordinate *viande*.

On the other hand, as demonstrated by Wierbicka [Wie85], nouns like *vegetable*, which describe functional properties, more than perceptual properties, cannot be considered real hyperonyms. Because of this, they are less susceptible to be used as a natural subsequent anaphora to designate a single element or a set of identical elements, unlike nouns such as *flower*, *viande* or *mushroom*. Consequently, we distinguish two different kinds of lexical anaphoric processes:

- **Superordination:** used to introduce a noun which refers to a set of different nouns (e.g. {carrots, leeks, tomatoes} → vegetables). This process obeys a principle of economy.
- **Basic denomination:** used to designate an element or a set of identical elements with the most natural term (e.g. {chanterelles} → mushrooms). This process obeys a principle of "naturalness" : it introduces the most closely basic noun that corresponds to the concept to be lexicalized.

Superordinate and basic denomination properties are features of the lexicon.

### 3.6 Conceptual constraints

Conceptual constraints are used mainly to check what kind of set the objects form. As seen above in (2), a pronominalization is not used in case of a heterogeneous set; instead, a verbal complement ellipsis is the anaphora of choice. Also, a typical result nominalization (e.g., *mixture*) will be prefered if the state of the elements has radically changed.

## 4 Implementation

To evaluate the linguistic constraints, a working text generation system has been implemented in Prolog [Kos92]. The goal of the system is to select and produce the most natural anaphora to refer to ingredients and instruments in cooking recipes. To test the constraints, the generator only needs to make tactical decisions. It therefore assumes the existence of a text planner, whose output is taken as the input to the system.

As almost all the rhetorical relations found in cooking recipes are action sequences [VL93], the input text plan exclusively specifies RST's relation of sequence [MT88]. That is, it only specifies user operations to be communicated in the text through action sequences. Figure 1 illustrates an example of the input text plan to make beef stew. Table 3, explained in detail later, shows the output text generated by the system. In addition, because the text plan is an abstract representation of the text, it uses as few lexical items and as many general concepts as possible. Operations are specified in the text plan by instances of general cooking operations (eg. `chauffer1` (*heat1*) on line (1)) to be specialized later by the realization system into specific verbs in the language. Participants are also specified by instances of concepts (eg. `boeuf1` (*beef1*) on line (5)) upon which the anaphoric constraints will be applied.

### 4.1 Representation Issues

To satisfy the lexico-grammatical, lexico-semantic and conceptual constraints set forth in section 3, the system uses a lexical and a conceptual dictionary.

The lexicon contains a taxonomy of lexical items of culinary French, along with their syntactic, lexico-semantic and morphological features. The taxonomy

```
(1) [[[sequence([action:chauffer1, objet:cocotte1]),
(2)    sequence([action:cuire1, objet:graisse1,
(3)              lieu:[valeur:cocotte1, prep:interieur_c],
(4)              source:feu1]),
(5)    sequence([action:cuire2, objet:boeuf1,
(6)              lieu:[valeur:cocotte1, prep:interieur_c],
(7)              source:feu1])],
(8)   [sequence([action:mettre1,
(9)              objet:(carotte1, laurier1, oignon1, sel1, poivre1, thym1),
(10)             objet2:(graisse1, boeuf1)]),
(11)   sequence([action:mettre2, objet:eau1,
(12)             objet2:(graisse1, boeuf1, sel1, poivre1,
(13)                     laurier1, thym1, carotte1, oignon1)])]],

(14)  [[sequence([action:mettre3, objet:couvercle1]),
(15)   sequence([action:mettre4, objet:regulateur_de_pression1]),
(16)   sequence([action:cuire3,
(17)             objet:(boeuf1, carotte1, graisse1, sel1, poivre1,
(18)                    laurier1, thym1, oignon1),
(19)             mod:mod3])],
(20)  [sequence([action:laisser_tomber1, objet:pression1,
(21)             mod:mod4])]],

(22)  [[sequence([action:faire1, objet:sauce1, acc:jus_de_cuisson1])]]].
```

**Fig. 1.** Text Plan for Beef Stew

links are based on generic term, typical result and syntactic name derivate (the LFs *Gener*, $S_{res}$ and $S_0$ in the Meaning-Text Model [Mel84]).

The conceptual dictionary stores the taxonomy of culinary concepts and allows the system to model the state change of the objects. Its structure is parallel to the structure of the lexicon except for lexical gaps. As noted in section 1.2, objects in assembly instructional texts are rather dynamic; therefore, as already shown by Dale [Dal92], to refer to these objects a text generator must model the objects' dynamic state. In our system, this modeling is done through the dictionary of concepts. Two basic concepts are stored: operations and participants. Participants are further classified as the agent, the objects manipulated (the ingredients) and the instruments. The dictionary of concepts stores the default state of the objects, the preconditions required to execute an operation and the postconditions triggered once an operation is executed (its effects on the state of objects). The current state of the procedure is kept in the dynamic structure $CS$ similar to Dale's *Working Set*. $CS$ is updated dynamically by the pre- and postconditions of operations as the text is generated.

To satisfy non-ambiguity, focus and distance constraints, a model of the previous textual context is also built dynamically as the text is generated (the $PTC$ structure). Among other entities, this structure contains the list of the participants and operations involved in the previous and current clauses, the local focus of the previous clause and the global focus of the text.

### 4.2 Overall Generation Process

The generation of a recipe is a two-stage process. First the text plan is fine-tuned locally:

1. Operations of preparation (e.g. peeling, washing) performed on an object $O$ are moved to the next reference of object $O$ in the text plan. This allows the operation of preparation to be realized as a past participle inside an NP (eg. *Fry the chopped potatoes.*)
2. Consecutive parallel semantic representations are merged into one in the text plan. This prevents syntactic parallel clauses to be created in the final text. This process is similar to Dale's optimization step[6].

At the second stage, instances of operations and of participants are lexicalized. To lexicalize operations, the most specific verbs in the current context are chosen to realize the general operation concepts of the text plan. This is done by descending the conceptual operation taxonomy until a precondition of a specific operation concept fails to be satisfied. For example, the operation `cuire1` (*cook1*, line (2)) of the text plan of figure 1 is realized in the corresponding text of table 3 by *fondre* (*melt*) because in its current state, the object being cooked (*grease1*) is solid and liquefiable when heated. Finally, the most natural anaphora is chosen to lexicalize the participants by satisfying the appropriate constraints. This last step will be fully described in the next section.

### 4.3 Selecting and Producing Anaphora

To choose an anaphoric device, the distinction between initial and subsequent reference is usually made [Dal92, McD80]. However, in assembly texts the initial list of participants stated before the procedural instructions should be taken into account. For most participants, this list provides an initial reference; but not all anaphoric devices can trace their antecedent back to this previous paragraph.

Of course, in initial reference, no anaphora can be used since there exists no antecedent yet: an indefinite NP or a non-coreferential definite NP is always produced. In subsequent reference, any anaphora can be used; however, if the previous reference is in the list of participants, an ellipsis, a pronominalization, a typical-result mention and a nominalization can be ruled out immediately. This is respectively due to lack of global focus, distance constraint (the antecedent of a pronoun cannot be in the previous paragraph) and lack of a previous operation

[6] It would be more appropriate to perform this step at the lexical level, but it is done here only to avoid costly backtracking and re-computation of new anaphoric choices.

performed on the referent.

To see how the constraints are verified, we will step through the generation of a complex coordination. Table 3 gives the recipe for beef stew generated automatically by the system from the input of figure 1. The recipe has been produced in French. Its English translation is given along with the selected anaphoric devices. We will step through the production of NP 5 `les légumes et les assaisonnements` (*the vegetables and the seasoning*). The conceptual description of this NP, line (9) in the text plan, is:

{`carotte1, laurier1, oignon1, sel1, poivre1, thym1`}
*[{carrot1, bay1, onion1, salt1, pepper1, thyme1}]*

First, by consulting the $PTC$ structure, it is determined that it is a subsequent reference of these ingredients in the text, but these previous references are located in the list of ingredients. A coreferential definite NP is therefore chosen (ellipsis, pronominalization, typical result mention and nominalization are ruled out immediately). To find the NP's lexical content, we try, the following anaphoric devices:

1. Superordination:
   This device is used if we are dealing with a set of objects sharing a common superordinate term and no other object previously included in the text shares this superordinate term.
   Conceptual constraints are satisfied because we have a set of objects. However, lexico-semantic constraints are not satisfied because, according to the lexicon, not all the objects share a common superordinate term. Note that to produce significant superordinates, we restrict the number of levels searched in the lexicon's taxonomy. Superordination is therefore rejected immediately without checking non-ambiguity constraints.
2. Complex coordination:
   To use this device, the only constraint is conceptual: the referent must be a set of objects. This constraint is satisfied, so the device is chosen. A complex coordination will coordinate a set of other anaphoric devices into one referring expression. To select these devices:
   (a) First the lexicon is searched to determine the direct superordinate of each object.

| **object** | **direct superordinate** |
|---|---|
| `carotte1` (carrot1) | *légume* (vegetable) |
| `laurier1` (bay1) | *assaisonnement* (seasoning) |
| `oignon1` (onion1) | *légume* (vegetable) |
| `sel1` (salt1) | *assaisonnement* (seasoning) |
| `poivre1` (pepper1) | *assaisonnement* (seasoning) |
| `thym1` (thyme1) | *assaisonnement* (seasoning) |

(b) Second, the system groups together objects that can be introduced using a superordination. The elements {*carotte1, oignon1*} share a superordinate term that is not ambiguous in the current context (there is no other vegetable in the recipe), they will therefore be introduced by *légumes*. Similarly, the elements {`laurier1, sel1, poivre1, thym1`} will also use the superordinate term *assaisonnements*.

(c) Finally, to mention the remaining elements, all anaphoric devices allowed in the previous step (all except ellipsis, pronominalization, typical result mention and nominalization) are applied. All elements have been treated so this last step is not performed.

The resulting coreferential definite NP is a complex coordination of two superordinations: *les légumes et les assaisonnements*.

### 4.4 Evaluation of the Constraints

The goal of the implementation is to evaluate the validity of the linguistic constraints. To do such an evaluation, we believe that a formal comparison of the source texts and the generated texts is a sufficient but not necessary condition. We believe that more subjective criteria are quite acceptable to evaluate how "natural" a generated text is. In the case of the beef stew text, as with all texts generated by the system, it is quite clear that the anaphora chosen are "natural"; furthermore, as the system took a few seconds to compute and generate the anaphoric devices of the text, the constraints result in a natural choice both linguistically and computationally.

## 5 Conclusion

In this paper, we have dealt with the problem of generating natural anaphora in French texts. To do so, a corpus study was performed on a particular type of texts: assembly instructional texts taking as representative cooking recipes. We found that the determination of grammatical anaphora is more dependent on the genre than is lexical anaphora, which appears governed by fairly general constraints.

The result of the analysis is a series of constraints for the automatic generation of anaphora. A working system, implementing these constraints, has then been developed. The system is a tactical component that takes as input the sequence of actions to be performed and selects and produces the most natural grammatical and lexical anaphoric references to ingredients and instruments in cooking recipes.

Further research includes considering other coreferential anaphoric devices, like "set" anaphora (e.g. *le tout*, *le reste* [all, the remaining ingredients]) and semantic anaphora still remains to be analyzed. Also, how the results can be extended to other textual genres and languages is an open question. Extending this research to other textual genres is, however, a very time-consuming endeavor as several tasks (identifying coreferents, focus determination, textual structures,

lexico-semantic relations) must be hand-located. As far as language is concerned, we believe that a dichotomy between grammatical and lexical anaphora appears[7], the former being more language dependent that the latter.

Lastly, it seems fundamental to consider longer texts, especially for lexical anaphora, grammatical anaphora being governed by fairly local constraints.


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| **Lexical Anaphora** | **Definition** | **Example** |
|---|---|---|
| Superordination | Replacement of a set of nouns by a superordinate term. | {carottes, poireaux, tomates} → légumes<br>{*carrots, leeks, tomatoes*} → *vegetables* |
| Basic denomination | Replacement of the antecedent by a less specialized and more natural term (basic noun). | girolle → champignon<br>*chanterelle* → *mushroom*<br>petites girolles → champignons<br>*small chanterelles* → *mushrooms* |
| Partial repetition | Repetition of the head noun without the modifiers of the NP. | petit lapin → lapin<br>*small rabbit* → *rabbit* |
| Strict repetition | Repetition of the antecedent. | lapin → lapin<br>*rabbit* → *rabbit* |
| Initial strict repetition | Repetition of the full initial NP. | un petit lapin ... le lapin → le petit lapin<br>*a small rabbit ... the rabbit* → *the small rabbit* |
| Nominalization | Nominalization of the antecedent verb or superordinate of the antecedent verb. | faire cuire le poulet → la cuisson du poulet<br>*cook the chicken* → *the cooking of the chicken* |
| Typical result mention | Replacement of the antecedent(s) by a noun expressing the result of the action carried out on these objects. | mélanger les patates$_i$ et les carottes$_j$ → le mélange$_{i+j}$<br>*mix the potatoes*$_i$ *and the carrots*$_j$ → *the mixture*$_{i+j}$ |
| Complex coordination | Two or more sets of antecedents are replaced by a single coordination of superordinates and/or other anaphora. | {petit lapin, grosses chanterelles} → le lapin et les champignons<br>{*small rabbit, big chanterelles*} → *the rabbit and the mushrooms* |

**Table 2.** Lexical Anaphora Studied

**Generated Recipe**

Pot-au-feu

4 livres de **bœuf à pot-au-feu**[0]
1 c. à soupe de **graisse**[0]
1 **carotte hachée** [0]
1 **oignon moyen haché**[0]
1/2 tasse d'**eau froide**[0]
1 **feuille de laurier** [0]
1/4 c. à thé de **thym**[0]
**sel** [0]
**poivre**[0]

Chauffer **une cocotte**[0], **y**[2] faire fondre **la graisse**[3] et **y**[2] faire revenir **la viande**[4]. Ajouter **les légumes et les assaisonnements**[5] et verser **l'eau**[6].
Mettre **le couvercle et le régulateur de pression**[1] et cuire ∅[7] pendant 35 minutes. Laisser tomber **la pression**[1] d'elle-même.
Faire **une sauce**[0] avec **le jus de cuisson**[1].

**Selected Anaphoric Devices**

[0] Initial Reference: Indefinite NP
[1] Initial Reference: Non-coreferential Definite NP
[2] Pronominalization
[3] Strict repetition
[4] Basic denomination
[5] Complex coordination of 2 superordinations
[6] Partial repetition
[7] Ellipsis of verbal complement

**English Version**

*Beef stew*

*4 pounds of* **beef for stew**
*1 table spoon of* **grease**
*1* **chopped carrot**
*1* **medium size chopped onion**
*1/2 cup of* **cold water**
*1* **bay leaf**
*1/4 tea spoon of* **thyme**
**salt**
**pepper**

*Heat* **a pressure cooker**, *melt* **the grease** *in* **it** *and brown* **the meat** *in* **it**. *Add* **the vegetables and the seasoning** *and pour in* **the water**.
*Put on* **the cover and the pressure regulator** *and cook* ∅ *for 35 minutes. Allow* **the pressure** *to fall.*
*Make* **a gravy** *with* **the meat sauce**.

**Table 3.** Generated Recipe and Selected Devices