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Abstract
We construct, in the framework of the lexicon-grammar theory, a set of grammars dealing with measure expressions. First, we manually represent compounds with graphs: determiners such as ten pounds of and prepositions such as 34 miles from. Then, by the means of lexicon-grammar matrices, graphs and a semi-automatic process, we build a set of grammars of kernel sentences e.g. the door is 2 meter high. Finally, we evaluate our methods and grammars according to three points: production, maintenance and concrete application.

1. Introduction
The representation of numerical expressions is a significant issue in Natural Language Processing (NLP) due to their very frequent occurrences in texts. In this paper, we build a set of grammars representing measure expressions in French and in English in the framework of lexicon-grammar methodology and with the aid of finite state technology. We first briefly present some points of the lexicon-grammar theory useful in our work (section 2). Then, we describe the process of constructing grammars of compounds in the form of graphs (section 3) and grammars of sentences (section 4). Finally, we evaluate our grammars (section 5).

2. Lexicon-Grammar Theory And Finite State Technology

2.1. Theoretical Bases
The Lexicon-Grammar is a systematic description of linguistic facts based on a transformational theory (Harris 1968; Gross 1975, 1994). The minimal unit of description is the elementary sentence. Predicates (verbs, nouns and adjectives) are systematically studied and encoded in Lexicon-Grammar Matrices (LGMs). Each lexical entry enters in an elementary surface structure according to which it is classified:

John eats a cake := N0 eat N1
Mary believes that John’s wrong := N0 believe that S
John makes a friend of Mary := N0 Ysup a friend of N1

Their transformational properties are systematically examined. Each lexical entry has its own behavior, such as the French verbs obèr (to obey) and penser (to think) with the same elementary structure N0 V à N1 (V for verb):

1 N0 stands for the ith nominal argument of a given predicate, where i is an integer.
2 S stands for a sentence.
3 Noun predicates enter in constructions with support verbs (Ysup).

Luc obèrt à Max – Luc lui obèrt
Luc pense à Max – * Luc lui pense

Nominalization and adjectivalization are also treated as in the following examples:

John analyses this problem
John makes an analysis of this problem
Mary has courage
Mary is courageous

In these cases, related predicates such as the noun analysis and the verb to analyse are encoded separately because they have different properties, but they are related to each other in the LGMs. Note also that constructions with noun predicates can be reduced into Noun Phrases (NPs): Max approves the analysis of this problem by John.

2.2. Linguistic Resources
Natural Language Processing (NLP) requires precise and large-scale linguistic databases. For this purpose, the informal European network of laboratories RELEX accumulates, in the framework of the Lexicon-grammar theory, linguistic components of three types in several languages (French, English, Portuguese, Italian, Korean, etc.): electronic dictionaries, local grammars and lexicon-grammar matrices (Leclère et al., 1991).

2.2.1. Electronic Dictionaries
Large-coverage morphological dictionaries of simple words have been built in order to recognize graphical words in electronic texts (Courtois & Silberman, 1990). Inflection codes are associated to canonical entries to automatically generate their inflected forms. Compound words have also been encoded in compound dictionaries. These dictionaries are part of the DELA system. They are compressed in the form of Finite State Transducers (FSTs), therefore improving access performances.

2.2.2. Local Grammars
Local Grammars are in the form of graphs and describe local constraints (Gross, 1997). They are

4 If S1 and S2 are sentences that have a transformational relation (in this case, pronominalization), they are equivalent in some ways and we write S1 = S2.
5 * is the interdiction sign.
equivalent to FSTs after a few compiling operations: they can be seen as compound dictionary extensions. In terms of production and maintenance, this compact representation is a clear advantage in comparison with the list representation of electronic dictionaries. The use of sub-graphs makes it very modular. Local grammars can be applied to texts e.g. with the software INTEX (Silberstein, 1993) in order to recognize and tag utterances (cf. section 3).

2.2.3. Lexicon-Grammar Matrices

For each predicate (verbs, nouns and adjectives), syntactic properties and syntactic and semantic information on arguments are systematically encoded in the form of LGMs. Each column corresponds to a given property (e.g. pronominalization, passivation). Each row corresponds to one lexical entry. At the intersection of a row and a column, a plus sign indicates that the corresponding lexical entry has the corresponding property, a minus sign, that it has not; and finally, a string indicates lexical information (cf. section 4.1). Part of the LGMs can be automatically transformed into FSTs e.g. to construct a syntactic parser (E. Roche, 1993, 1999). With each LGM entry, we associate a graph representing the set of its equivalent surface forms as shown in Figure 1. The different paths of the graph are equivalent. Graph representation can be seen as a factorization of the frames and the slots in the EAGLES terminology (Barnett et al., 1996). The optionality of an argument is marked by the presence of an empty transition in parallel with the argument.

3. Compounds And Measure Expressions

3.1. Base Structure

Our first objective is to represent determiner phrases like ten meters of and compound locative prepositions like ten miles from, containing measure expressions of the form Dnum Unit (=: fifty meters). Dnum stands for a numerical determiner described in a set of graphs that recognize utterances such as 34, 4 and sixty-one (Chrobot, 2000). Unit symbolizes units of measurement also represented in the form of graphs on the basis of Constant (2000) and describes utterances such as meter, foot plus their prefixed forms (e.g. kilometer), and their abbreviations (e.g. ft). Graph NUMBER shown in Figure 2 is part of Dnum and represents sequences of digits (e.g.

123 and 1.7). GRAM (Figure 3) represents English weight units and has been established with the aid of an on-line dictionary of units of measurement (www.unc.edu/~rowlett/units/). It is included in Unit.

![Figure 1: give](image1)

![Figure 2: NUMBER](image2)

![Figure 3: GRAM](image3)

We also need to use graphs of predicaments (PredDnum) and postdeterminers (PostDnum) that occur frequently before and after Dnum Unit, such as in environ 30 kilometers (about 30 kilometers) and 30 km, environ.

In English, currency units have a slightly different behaviour from other units: currency symbols are always located before Dnum: £10.

3.2. Determiner Phrases

We construct manually formal descriptions of compound determiners with the following basic forms:

*Det + E* Dnum Unit of = ten square meters of 
*Det + E* Dnum Unit de = six mètres carrés de

These determiner phrases have been studied in Buvet (1993). We propose a description with graphs. Their construction consists in assembling the graphs of section 3.1 and in choosing appropriate unit graphs (GRAM = gram, METER = meter, METER2 = square meter, METER3 = cubic meter, DOLLAR = dollar, DOLLAR S = £, SECOND = second + year). A simplified English graph is shown in Figure 4.

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6 This graph is a theoretical and simple example in order to help the reader’s understanding.

7 A symbol `s in a grey box represents a call to graph s. Graph Digit recognizes numbers from 0 to 9, x,y means that the space character is forbidden between the words x and y.

8 `<E>` is the empty symbol. For a given canonical form x, `<E>` stands for all inflected forms of x that are encoded in the dictionary.

9 Symbols in bold under boxes are the outputs of the graph.
When the graph is applied to a text, the utterances recognized are automatically tagged as in the following example:

Independent States sold the European Union
<DET>3,000 tons of <DET>uranium

Semantic information could clearly be added in outputs because such compound determiners contain significant meaning. For example, 3,000 tons of uranium can be related to the underlying sentence the uranium has a weight of 3,000 tons (Buvet, 1993, cf. section 4).

3.3 Locative Prepositions

We now describe semi-frozen locative prepositions (Loc) with the following basic forms:

Drum Meter from ~: 30 kilometers from
à Drum METRE de ~: à 30 kilomètres de

They enter in elementary constructions with locative support verbs (Gross, 1996): N0 Vstup Loc N1 (~: John is 30 kilometers from London). This sentence can be semantically interpreted by the distance d between the geographical positions P0 and P1 of N0 and N1: d(John, London) = 30 km. Such an interpretation can be performed with FSTs containing variables (Silberztein, 1999) as shown in the theoretical graph in Figure 5. Let u be a sub-sequence of an utterance recognized by the graph. If u is recognized by a part of the graph between indexed parentheses (), then u is indexed and is symbolized by the variable $i$. Thus, if the utterance John is ten meters from the swimming-pool is recognized, the result of the interpretation is d(John, the swimming-pool) ~: ten meters.

We show in Figure 6 a simplified English graph of the locative prepositions containing the unit Meter.

4. Sentences and measure expressions

4.1. Theory And Lexicon-Grammar Matrix Encoding

This section is based on a linguistic study by Giryschneider (1991). The elementary sentences we are concerned with have the following surface structures:

(1) N0 have a N of Drum Unit
   - Max has a weight of 80 kg
(2) N0 avoir un N de Drum Unit
   - Max a un poids de 80 kg

Each N has an appropriate set of units that can be represented by a graph. For example, graph GRAM describes the set of units appropriate to the noun weight.

Constructions (3) and (4) are equivalent to (2):

(3) N0 avoir Drum Unit de N
(4) N0 avoir Drum Unit de N
   - Cette corde a une longueur de 10 m
   (This rope has a length of 10 m)
   - Cette corde a 10 m de (longueur + long)

However, this permutation is not possible for all Ns as shown in the following example:

Cette voiture a une vitesse de 10 km/h

(4) N0 apro Drums Units de N
   - The rope is 10-meter long
   - The rope is 10 meters long

The adjetivization transformation on elementary sentences (1) and (2) yields the following structures:

N0 is Drum Unit N-a
-: The rope is 10-meter long
N0 être N-a de Drum Unit
-: la corde est longue de 10 m

Sentences (1) and (2) can also be the result of a nominalization of the sentences:

(5) N0 have a N of Drum Unit

-: The pen costs one euro
-: The pen costs one euro

Constructions (1) and (2) can also be reduced into NPs of the form (6). In some cases, N can be zeroed as in (7).

(6) N0 de un N de Drum Unit

- N de Drum Unit de (N + N-a)
- une porte d’ une hauteur de 3 m

10 Unit can be interpreted by the application of transducers that convert each unit into a standard one, e.g. kilometer ~: 1000 m. Drum can be converted into a sequence of digits, such as sixty-one ~: 61 (Chambers 2000). Thus, Drum Unit can be seen as a simple multipication.

11 N-a (~: long) is the adjective morphologically and semantically associated to N (~: length). Some Ns have no N-a, e.g. speed.
12 N-v (~: to weigh) is the verb morphologically and semantically associated to N (~: weight). Some Ns have no N-v, e.g. length.
From these observations, we build a LGM a selection of which is shown in Table 1. C1 indicates the Ns described. C2 provides the names of the graphs representing the sets of units appropriate to N. C3 and C4 give respectively N-a and N-v. C5 indicates if N enters in construction (3). In our selection, the French word tension has two entries: the first one means tension, the other one means blood pressure. They have different appropriate units: the blood pressure has an empty unit symbolized by $<E>$ while volt is associated to the electric tension. They also have different transformational properties: Max à 13 de tension

* Cette ampoule a 60 V de tension

Note also that we could add a new column in the LGM to indicate appropriate modifiers of N, such as artérielle (arterial) for tension (blood pressure) or électrique (electric) for the other tension.

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>longeur</td>
<td>:MÉTRE</td>
<td>long</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Poids</td>
<td>:GRAMME</td>
<td>-</td>
<td>peser</td>
<td>-</td>
</tr>
<tr>
<td>Tension</td>
<td>:VOLT</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Tension</td>
<td>$&lt;E&gt;$</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Vitesse</td>
<td>:KMH</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1: Measure sentence LGM

4.2. Reference Graph And Lexicon-Grammar Matrices

In section 2.2.3, it has been mentioned that an LGM can be semi-automatically transformed into graphs. A simple way of doing this is to build a reference graph that contains the set of all possible surface forms as shown in Figure 7. A transition @i (where i is an integer) is seen as a variable that refers to the ith column (or property) of the matrix. For each lexical entry (or each row), a new graph is automatically constructed from the reference graph by:
- removing the transition @i when the intersection of the ith column and the current row is "+1
- replacing @i by $<E>$ (the empty element) when "-1
- replacing @i by the content of the intersection of the ith column and the current row, by default

The result of the process for the entry longueur is shown in Figure 8.

5. Evaluation

We evaluate our methods and our grammars by taking into account three points: production, maintenance and application.

5.1. Production And Maintenance

Through the examples shown previously, it should be clear that graph formalism facilitates the production of grammars. The application of our methods has to be manually controlled in order to construct precise lexicons based on linguistic facts: each lexical entry has a specific syntactic behaviour that cannot be entirely automatically predicted. Nevertheless, the use of automatic tools extracting information from large corpora makes this work less time-consuming. For example, in order to build our compound grammars, we built unit graphs with the aid of specific dictionaries, and then their application to a large corpus provided a list of occurrences. By examining their left and right contexts, we manually extracted relevant information e.g. the list of determiners. Furthermore, the use of LGMs, reference graphs and the semi-automatic process shown in section 4 avoids duplicating graphs by hand.

Maintenance is possible with our formalism. In graphs, the insertion of a new path is a very simple operation: inserting new transitions. The modification of a sentence grammar is also extremely simple and cheap. For example, the addition of a new property to a sentence grammar (e.g. appropriate modifiers) only requires adding a column in the LGM, modifying the reference graph and automatically generating the modified graphs for each lexical entry.

5.2. Concrete Application

The graphs of compounds shown previously are simplified and theoretical. Thus, we need to improve them in order to apply them to texts, which complicates graphs. We provide below a list of examples of improvement.

The theoretical sequence Dnum Unit used to describe the basic form of measure expressions does not exactly correspond to usage though most expressions of this type occur in texts. Each unit has its own syntax, e.g.

- 2 hours, 15 minutes and 2 seconds
- 5 feet and 2 inches

Graphs are manipulated by the means of an editor (e.g. FSGraph in INTESX).
Thus, instead of dividing the sequence Dnum Unit into two graphs for each set of unit (e.g. Dnum METER, Dnum GRAM, etc.), we have to construct one graph DnumUnit (e.g. DnumMETER). As explained previously, these modifications in graphs are very simple to make. In column C2 of the Table 1, we replace Unit (= GRAM) by DnumUnit (= DnumGRAM) and then modify the reference graph.

The working corpus may also have a specific way of dealing with measure expressions. We shall adapt our grammars to it. For example, the electronic version of the newspaper Herald Tribune often juxtaposes measures in British units and their conversion into standard units, e.g. It produced 1.2 million ounces (34,000 kilograms) of gold last year.

Application to sentences is more difficult than to locally constrained expressions such as compounds because they rarely occur in their theoretical elementary form. Measure expressions most of the time occur in the form of NPs and Adjective Phrases (APs) transformationally related to the elementary sentence. With the aid of transformational properties, NPs and APs, when recognized, are automatically related to their elementary sentences:

- a 13-meter-long rope
- une corde de 13 mètres de long
- a five-day waiting period
- une période d’attente de cinq jours
- a 23-foot-long, three-ton hot dog

6. Conclusion

In this paper, we have described, in the framework of the lexicon-grammar theory, the construction of a set of finite state grammars of measure expressions in French and in English: compounds and sentences. We have also shown that our grammars based on the lexicon and the syntax is of great interest for the semantic interpretation of such expressions.

7. Acknowledgments

I would like to thank my director Eric Laporte for his help.

8. References


14 In order to obtain better results for elementary sentence application, we shall, for example, insert new support verbs, adverbiais between arguments,...