# SMM: Detailed, Structured Morphological Analysis for Spanish

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***Abstract*—We present a morphological analyzer for Spanish called *SMM*. SMM is implemented in the grammar development framework *Malaga*, which is based on the formalism of *Left-Associative Grammar*. We briefly present the Malaga framework, describe the implementation decisions for some interesting morphological phenomena of Spanish, and report on the evaluation results from the analysis of corpora. SMM was originally only designed for analyzing word forms; in this article we outline two approaches for using SMM and the facilities provided by Malaga to also generate verbal paradigms. SMM can also be embedded into applications by making use of the Malaga programming interface; we briefly discuss some application scenarios.**

***Index Terms*—Natural language processing, morphology, Malaga, Spanish.**

## I. Introduction

MORPHOLOGY is one of the core processes of language. By applying the rules for inflection, derivation, and compounding, humans are able to create and understand the word forms required to communicate, including the creation of new words from existing words. To understand an utterance in some language we have to know the rules of syntax and morphology, as these are essential prerequisites for dealing with semantics or even pragmatics.

>From the point of view of computational linguistics, morphological resources form the basis for all higher-level applications. A morphological component should thus be capable of analyzing single word forms as well as whole corpora, and it should provide detailed analyses describing the relevant morphological processes. For evaluation purposes, it should also provide statistical information on speed, accuracy, etc. when analyzing large corpora.

The *Malaga* system provides a framework that supports both the development of morphological components and their application. In section II, we will give a short overview of the Malaga framework and the underlying formalism of *Left-Associative Grammar*. In the rest of this article, we will then present a specific application of Malaga, a morphological component for Spanish – the *Spanish Malaga Morphology (SMM)*.

In section III, we describe some important morphological phenomena of Spanish and present a number of principles for handling these phenomena, which guided the design of SMM. In section IV, we describe the implementation of SMM. Section V reports on the performance of SMM on two corpora. This is followed by an overview of related work (section VI) and a discussion of the use of SMM in a variety of applications. Section VIII summarizes the properties and specific advantages of SMM and outlines future work.

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## II. Malaga and Left-Associative Grammar

Malaga is a software package for the development and application of morphology and syntax grammars based on the *Left-Associative Grammar* (LAG) formalism [1], providing a specialized programming language and associated development tools.

Left-Associative Grammar is based on non-deterministic finite automata. As implemented in Malaga, the analysis states are augmented by arbitrarily complex feature structures. In a morphology grammar, the symbols read from the input are allomorphs. The feature structures allow to store all available information about the involved allomorphs and the values resulting from the concatenation of these allomorphs. For the presentation of analysis results the information can be filtered to show only the features needed for a certain purpose.

Morphological components implemented in Malaga are based on the *allomorph approach*, which we will briefly describe in section IV-A.[1] Thus, the run-time lexicon used by Malaga grammars is an *allomorph lexicon* generated from a base form lexicon by applying allomorphy rules at compile time.[2]

Malaga is able to process text in UTF-8 encoding. Besides the morphological component for Spanish described in this paper, a number of Malaga grammars for morphological and syntactical analysis of English, Finnish, German, Italian, and Korean have been created, both at the University of Erlangen (Germany), where Malaga was originally developed, and elsewhere.

Malaga is freely available under the GNU Public License (GPL). For the work described in this paper we used Malaga version 7.12 on Mac OS X and Linux.[3]

[1] See [2] for a comparison of methods for morphological analyzers.

[2] See Björn Beutel: *Malaga. A Grammar Development Environment for Natural Languages*, http://home.arcor.de/bjoern-beutel/malaga/ [last access 2009-02-04].

[3] We have also used this and earlier versions of Malaga on various versions of Solaris, HP-UX, and NetBSD.

## III. Spanish Morphology

Spanish, an Ibero-Romance language, is one of the most widely-spoken languages of the world. On the grounds of its rich verbal morphology it can be classified as an inflecting language; however, almost all of the noun inflections have disappeared, with only a plural marker remaining.

In this section, we will give a short overview of morphological processes and phenomena of Spanish, and briefly describe orthographical issues. We will present them in a way that allows us to define principles for the implementation of SMM.

### A. Derivation

Verbs, adjectives, and nouns can form the base of a derivation. The base for derivation can be a simple word as well as a compound. Derivation happens through suffixes, prefixes, or a combination of both. Only suffixes can change the word class. Some suffixes require the insertion of a preceding interfix. Derivation includes conversion; e.g., participles of verbs can be used as adjectives.

Multiple derivations are possible, e.g., *inutilizable* 'unusable' is derived from the adjective stem *util* by adding the negating prefix *in*, the verbalization suffix *iza*, and the adjectivization suffix *ble*. In many such cases, the exact bracketing is debatable, e.g., whether the prefix was added to the result of the suffixation (*in+utilizable* 'un+usable') or whether suffixes were added to the result of the prefixation (*inutil+izable* 'unus+able'). Since there is no way for a morphological analyzer to determine the "correct" bracketing, it should thus *keep ambiguity with respect to bracketing and return it in a way that allows subsequent applications to resolve it.*

### B. Compounding

Compounding – in the sense of combining free morphemes or well-formed word forms to form new words – is not used in Spanish to the extent it is used in languages like German. Compounds can be written as one word form (*sordo + mudo → sordomudo* 'deaf-mute'), with hyphens (*actor-cantante* 'singer-actor'), or as separate word forms (*treinta y uno* 'thirty-one'). Compounds written as separate word forms cannot be recognized by a morphological analyzer examining one word form at a time, but only by a tagger or during syntactical analysis.

Most compounds in Spanish are nouns or adjectives. Compounds can be constructed from nouns, adjectives, adverbs, and verbs. It is not always possible to unambiguously determine the resulting part of speech (POS). The principle is thus to *keep ambiguity with respect to POS and return it in a way that allows subsequent applications to resolve it.*

### C. Inflection

Spanish word classes can be categorized into inflected classes (adjectives, nouns, determiners, pronouns, and verbs) and uninflected classes (adverbs, prepositions, conjunctions, interjections). There are two basic types of inflections, noun inflection and verb inflection. Only suffixes are used in inflection.

*1) Noun Inflection:* The principles of noun inflection apply to nouns, adjectives, determiners, pronouns, and numerals. For nouns and adjectives, gender and number are marked in the surface of word forms. Case is not marked and can therefore only be determined during syntactical analysis.

Pronouns and adverbs share many forms: When looking at an isolated word form it is not always possible to decide whether it is used as a pronoun or an adverb; we therefore assign the POS *Pronoun/Adverb*, and the analysis includes all information for both the pronominal and the adverbial readings. The final decision can only be made during syntactic or semantic analysis. Thus, as in the case of compounding, an implementation should *keep ambiguity with respect to POS and return it in a way that allows subsequent applications to resolve it.*

As the feature structures of Malaga are not restricted to a certain number of features or a certain structure of values, we propose to *gather as much information as possible during the analysis process*. If some of this information is not needed or wanted for a certain purpose it can easily be filtered out, which is much cheaper than trying to infer missing information.

*2) Verb Inflection:* In contrast to nouns and adjectives, the verbal inflection system is very rich. There are 17 possible combinations of mood and tense [3]; as verb forms are also marked for person and number, there are 111 word forms for each verb. However, some of these word forms share the same surface, so that it is not always possible to determine the exact category from the surface of an isolated word form. For example, the word form *cantara* (of *cantar* 'to sing') can be first *and* third person singular subjunctive imperfect. We therefore use the approach of *distinctive categorization* [1, pp. 244, 346]: Instead of postulating different word forms which are indistinguishable at the surface level, we only assume *one* word form which can have different functions. This drastically reduces the number of surface forms per verb to 52 – which still is very high when compared to English.

Spanish has three main conjugation classes, distinguished by the *theme vowel* (*a*, *e* or *i*) in each form of a verb. The information for person and number is marked using a single morpheme, and tense and mood are also indicated by a single morpheme. Traditional grammars (e.g., [4], [5]) thus arrive at the following segmentation for the word form *cantábamos* (first person plural indicative imperfect):

> *cant* (stem) + *a* (theme vowel) + *ba* (mood/tense) + *mos* (person/number)

However, as the combination of allomorphs for theme vowel, mood/tense, and person/number results in distinct strings for each combination, *cantábamos* can also be analyzed as

> *cant* (stem) + *abamos* (inflectional ending)

The ending is thus considered to contain all inflectional information. The ARIES system [6], [7] takes the same approach.

This leads to a further principle for the implementation: *Treat verbal inflection as concatenation of stem allomorph and inflectional allomorph. The inflectional morphemes yield all categorial information that will be presented in the result of an analysis.*

Traditionally, Spanish verbs are categorized as either *regular* or *irregular*. Irregular Spanish verbs exhibit irregularity only in the stem, the inflectional suffixes remain the same. Irregularities in the verbal stem may concern vowels only, consonants only, or vowels and consonants.

In fact, however, most of the "irregular" variation still follows certain rules. We therefore distinguish between *regular* (no variation), *semi-regular* (the variation can be derived from the surface of the base form), *semi-irregular* (the variation must be derived from a special surface marker), and *irregular* (suppletive) verbs, following the classification of Hausser [1, p. 263].

### D. Orthographic Characteristics

Some orthographic conventions affect morphological analysis and generation. One case are accents. Spanish has certain fundamental stress patterns, e.g., word forms ending in a vowel, in *n*, or in *s* have penultimate stress. These cases are unmarked in Spanish orthography. If stress differs, the stressed syllable is marked by an acute accent (e.g., *derivación* 'derivation'). If phonologically legal, stress remains on the original syllable even if the number of syllables changes due to morphological processes. It can therefore be necessary to add, move, or remove an accent.

A similar case are phonemes that are represented by different allographs depending on the following vowel, e.g., /g/ is written as *g* before *a*, *o*, and *u*, and as *gu* before *e* and *i*.

While these are, strictly speaking, orthographic phenomena, it is necessary to handle them in a morphological component. This leads to a further principle: *Treat orthographic variants as allomorphs*.

### E. Clitical Pronouns

Spanish is a language using clitical pronouns (*pronombres átonos*). Up to three clitical pronouns can follow a verb, e.g., *¡búsquesemelo!* 'find (pl.) it for me!'. Clitical pronouns can represent direct and indirect objects; the reflexive pronouns can also be used clitically.

It is debatable whether this is a morphological or a syntactical phenomenon: If a noun phrase is used instead of a clitical pronoun, the verb and the object are written as separate word forms, and thus do not appear to be a single word form. As an example, compare *¡dámelo!* 'give it to me!' to *¡da el libro a Maria!*[4] 'give the book to Maria!'; here, *me* is replaced by *a Maria* and *lo* is replaced by *el libro*.[5] If noun phrases are used, it is obviously the task of a syntactical component to check whether the phrase *el libro* is a valid valency slot filler for *¡da!*.

However, convention requires that a verb (in certain forms) and following pronouns are written without intervening spaces, thus giving the impression of being a single word form. The resulting "word form", though, is *not* part of the paradigm of the verb, as it results from neither derivation, nor compounding, nor inflection. We thus postulate a further principle: *The analysis of verb forms with clitical pronouns has to make clear that the surface consists of more than one word: The verb and the clitical pronouns.*

## IV. Implementation of SMM

### A. Principles and Approach

In section III we formulated several requirements we wanted our implementation to meet. To summarize, these are:

- Keep ambiguity with respect to bracketing and return it in a way that allows subsequent applications to resolve it.
- Gather as much information as possible during the analysis process.
- Use distinctive categorization.
- Treat verb inflection as concatenation of stem allomorph and inflectional allomorph.
- Distinguish regular, semi-regular, semi-irregular and irregular inflection.
- Treat orthographic variants as allomorphs.
- The analysis of verb forms with clitical pronouns has to make clear that the surface consists of more than one word: The verb and the clitical pronouns.

Furthermore, there are often several possible segmentations into allomorphs for a word form, all morphologically legal, but only some are likely to be semantically or conventionally acceptable. As a general principle, when ambiguity cannot be resolved on the level of morphology, a morphological component should not attempt to resolve it, as it could only guess. Instead, it should gather and return all relevant information, so that a higher-level component can use it to make a decision.

As noted above, SMM is based on the *allomorph approach* to morphological analysis: During analysis, word forms are segmented into allomorphs, which are then looked up in an allomorph lexicon; concatenation rules then combine the allomorph entries from the lexicon to determine lemma and category of the word form. The allomorph lexicon is generated (compiled) from a morpheme (base form) lexicon before run time; this means that during run time, only computationally cheap matching and concatenation operations are necessary. In contrast to systems based on full-form lexicons, the allomorph approach allows to analyze ad-hoc creations and neologisms, since the rules reflect the morphological processes of the language, and it only requires a relatively small base form lexicon.

SMM thus consists of three components: (1) The base form lexicon, (2) rules for creating allomorphs from these base forms (allomorphy rules), and (3) rules for concatenating these allomorphs at run time.

[4]Note that the accent on the verb is removed.

[5]Syntactical rules require different word order.

### B. The Base Form Lexicon

The SMM base form lexicon contains 98,545 entries (see table I).

TABLE I
COMPOSITION OF THE SMM BASE FORM LEXICON

| POS | # entries |
|---|---|
| Nouns | 57,882 |
| Adjectives | 21,867 |
| Verbs | 12,826 |
| Adverbs | 2,517 |
| Names | 1,030 |
| Acronyms | 537 |
| Interjections | 317 |
| Pronouns | 89 |
| Affixes | 1130 |
| Inflectional morphemes | 126 |
| Other | 214 |
| **Total** | 98,545 |

Listing 1 shows three entries from the base form lexicon; *comer* 'to eat' is a regular verb, *huir* 'to flee' is a semi-regular verb (no markers required), and *decir* 'to speak' is a semi-irregular verb (the `AlloMark` feature contains the surface marker and the `AlloForm` feature indicates the applicable allomorphy rule).

```
[Lemma: "comer",
 POS: Verb,
 Valencies: <Reflexive, Intransitive, Transitive>];
[Lemma: "huir",
 POS: Verb,
 Valencies: <Reflexive, Intransitive>];
[Lemma: "decir",
 POS: Verb,
 Valencies: <Reflexive, Transitive>,
 AlloMark: "d{ec}", AlloForm: Allo_Norm_ecir1,
 P_imp_Sg2: <"di">, Participle: <"dicho">];
```

Listing 1. Entries for *comer*, *volver* and *decir* in the base form lexicon

An allomorph lexicon of 168,392 entries is generated from the base form lexicon by applying *allomorphy rules*, which take lexicon entries as input and create entries for the allomorph lexicon. The compilation of the allomorph lexicon takes about 9 seconds on an Apple MacBook[6].

The ratio of allomorphs per base form in SMM is 1.709. This is much higher than the ratio observed in other morphological systems implemented with Malaga [1, p. 268]. However, a large portion of the allomorphs differ only in the presence of a diacritical accent or due to orthographic rules as described in section III-D. Treating these variants as allomorphs is in line with other systems [6], [8], [9], [7] and allows for uniform processing, but the side effect is a high allomorphy quotient.

### C. The Allomorphy Rules

The entries of the allomorph lexicon contain many more features than the original base form entries. The features from the base form entries are copied to the allomorph entries. Based on the POS and the surface specified in the base form entry, the allomorphy rules deduce certain features such as the theme vowel and the conjugation type for verbs.

[6]2.16 GHz Intel Core 2 Duo processor, 2 GB RAM, running Mac OS X 10.5.5.

```
"com": [POS: Verb,
        Valencies: <Reflexive, Intransitive,
                    Transitive>,
        BaseForm: "comer",
        ThemeVowel: e,
        PossibleEnclitics: 2,
        Suc: <<<POS, ThemeVowel>>,
              <<POS, Suffix>>,
              <<POS, Interfix>>,
              <<POS, VerbInflection>,
               <Tempus, <Inf, P_imp_Pl2, ...>>>>,
        SucFon: aeiou,
        Pre: <<<POS, Prefix>>,
              <<POS, Adverb>>,
              <<POS, Substantive|Adjective>,
               <WellFormed, yes>>,
              <<LastPOS, Punctuation>>>,
        Conjugation: regular]
"cóm": [POS: Verb,
        Valencies: <Reflexive, Intransitive,
                    Transitive>,
        BaseForm: "comer",
        ThemeVowel: e,
        PossibleEnclitics: 2,
        Suc: <<<POS, ThemeVowel>>,
              <<POS, Suffix>>,
              <<POS, Interfix>>,
              <<POS, VerbInflection>,
               <Allo_i, <encl1>>,
               <Tempus, <P_imp_Sg2, ...>>>>,
        SucFon: aeiou,
        Pre: <<<POS, Prefix>>,
              <<POS, Adverb>>,
              <<POS, Substantive|Adjective>,
               <WellFormed, yes>>,
              <<LastPOS, Punctuation>>>,
        Conjugation: regular]
```

Listing 2. Entries for *comer* in the allomorph lexicon.

Listing 2 shows the entries in the allomorph lexicon (with some feature values omitted) generated by allomorphy rules from the base form entry for *comer* (see listing 1). For the reasons outlined in section III-D, there are two allomorphs (*com* and *cóm*), even though *comer* is a regular verb.

All allomorph lexicon entries contain the two features `Pre` and `Suc`. `Pre` contains a list of features the preceding concatenated allomorphs have to have; `Suc` contains a list of features a following allomorph has to have. The `Pre` and `Suc` features essentially represent the morphological processes (inflection, derivation, compounding) and constraints on the level of allomorphs. For example, stem allomorphs of verbs include `<POS, VerbInflection>` in their `Suc` feature list, so that they can be followed by a verbal inflectional allomorph; verbal inflectional allomorphs, on the other hand, include `<POS, Verb>` in their `Pre` feature list. Similarly, prefixes cannot be followed by suffixes, etc.

The `Pre` and `Suc` features can also describe more specific constraints; see, e.g., the last `Suc` entry for *cóm* in listing 2,

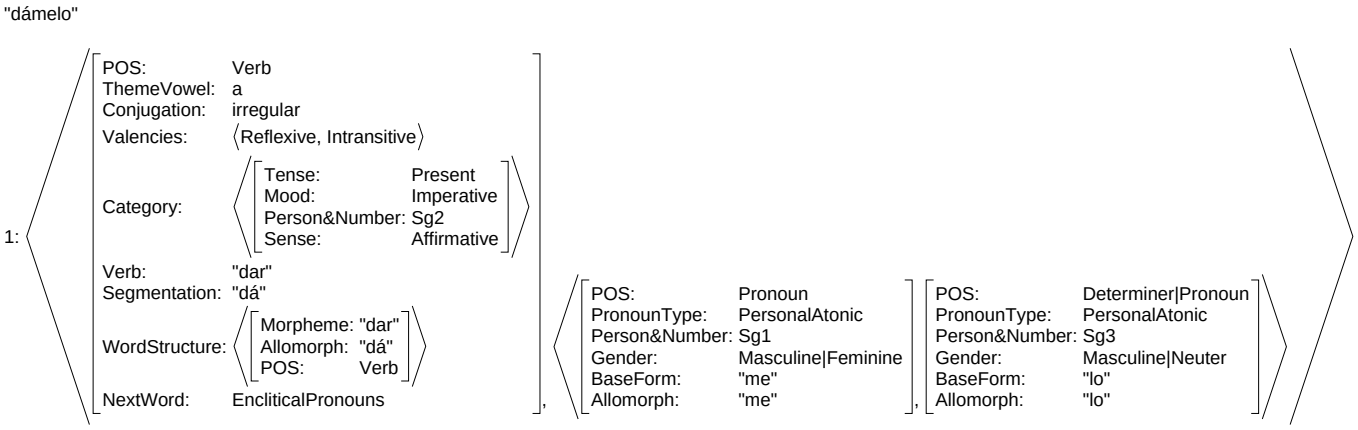


Fig. 2. Analysis of *¡dámelo!*

of the generation grammar primarily consist of mechanical agreement checks.

The second approach utilizes the `mg` function of Malaga. This function takes a list of allomorphs and a number indicating the maximum number of concatenated allomorphs as arguments. As result, the function returns all word forms that can be constructed from the given allomorphs, up to the indicated length. However, the result may include word forms not belonging to the paradigm, so it is necessary to filter the results, e.g., by using a small Perl script.

As we have described in section III-C2, we treat verbal inflection as the concatenation of a lexical stem and an inflectional morpheme (combining theme vowel, mood, tense, person and number). To generate the paradigm of a verb we can thus call `mg` with all allomorphs of the verb and all inflectional allomorphs and a maximum length of 2.

## V. Performance and Evaluation

To measure the analysis speed and to get an impression of the performance we morphologically analyzed two corpora using SMM: The CRATER corpus[9] and a home-grown Web corpus (called WaC – Web as Corpus).

The CRATER corpus is a parallel English, Spanish, and French corpus consisting of ITU (International Telecommunications Union) documents. We used the manually tagged Spanish part and excluded all multi-word terms, foreign words, and non-word tokens[10] The WaC corpus was constructed by the method described by Sharoff [12], using the 500 most frequent Spanish word forms[11] as "seed words." Table II shows the detailed results for both corpora (WF: word forms). The performance data was collected on a Linux system[12].

The unrecognized word forms in the CRATER corpus are mostly typos and mistagged tokens. The recognition rate for WaC is lower, as the Web texts contain more typos, unmarked foreign words, non-standard abbreviations used in blogs and forums, etc. With respect to unique word forms, the recognition rate for WaC is extremely low. Furthermore, the difference between the recognition rates for WaC with respect to running word forms and unique word forms is much higher than the respective numbers for CRATER. However, most (86%) of the unrecognized word forms in WaC appear less than 5 times. Excluding these low-frequency unknown tokens increases the recognition rate to 93.2% for running word forms and to 84.7% for unique word forms.

## VI. Related Work

There exist a number of other systems for automatic morphological analysis of Spanish word forms.

ARIES is a set of tools developed at the Universidad Politécnica de Madrid (UPM) [9], [7]. The morphological analyzer concentrates on inflection. From a base form lexicon of 38,000 entries 465,000 inflected forms are created using allomorphy rules. ARIES seems to be no longer maintained.[13]

COES [8], [13] is being developed at the UPM and the Universidad Carlos III. The COES tools are based on a lexicon of about 50,000 words, handle inflection, enclitic pronouns, and some types of derivation, but, as they are intended for spell-checking, do not provide analyses. COES has been integrated with ispell and is available under the GPL since 1994.[14]

AGME [14] was developed at the Instituto Politécnico Nacional, Mexico. It can be used for morphologic analysis and

[9]Corpus Resources And Terminology ExtRaction, see http://www.lllf.uam.es/ESP/proyectos/crater.html [last access 2009-02-04].

[10]Such as acronyms and numbers. Most of these tags are not listed in the documentation [11].

[11]Created from the list of the 1000 most frequent Spanish word forms from the *Corpus de referencia del español actual* of the Real Academia Española, http://corpus.rae.es/frec/1000_formas.TXT [last access 2009-02-04].

[12]2.2 GHz Dual-Core AMD Opteron Processor, 8 GB RAM, running Ubuntu 8.04 for x86-64.

[13]See http://www.mat.upm.es/~aries/ [last access 2009-02-04].

[14]See http://www.datsi.fi.upm.es/~coes/ [last access 2009-02-04].

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