Onoma: A Linguistically Motivated Conjugation System for Spanish Verbs

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Abstract. In this paper we introduce a new conjugating tool which generates and analyses both existing verbs and verb neologisms in Spanish. This application of finite state transducers is based on novel linguistically motivated morphological rules describing the verbal paradigm. Given that these transducers are simpler than the ones created in previous developments and are easy to learn and remember, the method can also be employed as a pedagogic tool in itself. A comparative evaluation of the tool against other online conjugators demonstrates its efficacy.

1 Introduction

Although the literature about online Spanish conjugators is scarce, it does reveal that some are fully memory based (DRAE)[3] while others rely on finite state morphological rules [17][4].

To the best of our knowledge, the goal of most of the work related to verbal morphology was not the creation of an end-user tool such as a conjugator. However, both machine learning and rule-based approaches have been taken into consideration when processing inflectional morphology. While instance based-learning algorithms can induce efficient morphological patterns from large training data [2, 1, 5, 13], approaches using finite state transducers [19, 8, 6] do enable the implementation of robust morphological analyzer-generators which are successful in handling concatenation phenomena [4].

The Onoma conjugator[5] was implemented as a cascade of finite state transducers that implements a decision tree. The use of finite state transducers (FSTs)

⋆ While developing this work the first author's institution was Molino de Ideas s.a.

[3] Conjugator from the Dictionary of the Royal Spanish Academy (DRAE). Available at: http://buscon.rae.es/draeI/

[4] The conjugator developed by Grupo de Estructuras de Datos y Lingüística Computacional (GEDLC) at the University of Las Palmas de Gran Canaria, which is available at: www.gedlc.ulpgc.es/investigacion/scogeme02/flexver.htm

[5] Developed and funded by Molino de Ideas. http://conjugador.onoma.es

provides the possibility of generating verbal paradigms as well as the reverse process: the analysis of inflectional verb forms [9]. Further, the use of a cascade structure facilitates the implementation of ordered alternation rules [10, 11].

The remainder of the paper is structured as follows: the data and methodology used in this study is explained in Section 2, while Section 3 describes Spanish verbal morphology. Section 4 discusses the architecture of the system. A comparative evaluation of the system against other online conjugators is presented in Section 5. Finally, in Section 6, conclusions are drawn.

2 Data and Methodology

A database named the MolinoIdeas Verb Conjugation Database (MIVC-DB) was used for the modeling process. It contains 15,367 verbs (plus their corresponding verbal paradigms) including all the verbs registered in the Royal Spanish Academy Dictionary (11,060 verbs) [15], the Spanish Wikipedia, and the verbs found in a collection of 3 million journalistic articles from newspapers written in Spanish from America and Spain[6].

Our conjugator differs from the other Spanish processors in its architecture [17] (the GEDLC conjugator relies on the interaction of a segmentation program, three lists containing prefixes, verbal endings and pronouns, and two modules: one for the verbal endings and another for obtaining required external information) and in the design of the transducers, which are not based on concatenation rules [19] (in this FST model, a specific ending is added to 62 conjugation classes, giving as a result almost 150 verb-stem final states), but on rules which modify a hypothetical regular verb form, providing the possibility to extend such rules for the conjugation and analysis of verb neologisms in Spanish.

When designing the rules and patterns for each FST, the Spanish verbal inflectional paradigm was analyzed in detail from a linguistic point of view. This analysis led to the derivation of a simpler description of the inflectional verb paradigm which can be fully expressed (except for six verbs, see Section 4) using just nine patterns and a set of rules, as opposed to approximately one hundred and twenty conjugation models as in other approaches [7, 18]. Given that the FSTs used in this system are easy to learn and remember, the description can be employed as a pedagogic tool in its own right by students of Spanish as a foreign language. It helps in the learning of the Spanish verb paradigm since currently existing methods (e.g. [14, 12]) do not provide guidance on the question of whether verbs are regular or irregular. This is due to the fact that the system can identify the nature of any possible verb by reference only to its infinitive form[7] following just seven steps. [16].

For the design of the algorithm, in order to validate the rules and patterns extracted from the analysis of the MIVC-DB, an error-driven approach was taken.

[6] Newspapers with the major representation in our corpus are: *El País, ABC, Marca, Público, El Universal, Clarín, El Mundo* and *El Norte de Castilla*

[7] In some rare cases, external information which the system also provides is required, see Section 4.

3 Spanish Verb Morphology

In Spanish, inflected verb forms exist for the nineteen tenses/moods as shown in Table 1[8].

Tense/mood	**Examples, verb *ayudar* (to help)**
present tense/indicative	*ayudo*, 1st person singular
present tense/subjunctive	*ayude*, 1st person singular
present tense/imperative	*ayuda*, 2nd person singular
preterite imperfect tense/indicative	*ayudaba*, 1st person singular
preterite imperfect tense/subjunctive 1	*ayudara*, 1st person singular
preterite imperfect tense/subjunctive 2	*ayudase*, 1st person singular
preterite perfect composed tense/indicative	*he ayudado*, 1st person singular
preterite perfect composed tense/subjunctive	*haya ayudado*, 1st person singular
past perfect tense/indicative	*ayudé*, 1st person singular
past perfect composed tense/subjunctive	*hube ayudado*, 1st person singular
preterite pluscuanperfect tense/indicative	*había ayudado*, 1st person singular
preterite pluscuanperfect tense/subjunctive 1	*hubiera ayudado*, 1st person singular
preterite pluscuanperfect tense/subjunctive 2	*hubiese ayudado*, 1st person singular
future tense/indicative	*ayudaré*, 1st person singular
future tense/subjunctive	*ayudare*, 1st person singular
future perfect tense/indicative	*habré ayudado*, 1st person singular
future perfect tense/subjunctive	*hubiere ayudado*, 1st person singular
conditional simple tense/indicative	*ayudaría*, 1st person singular
conditional perfect tense/indicative	*habría ayudado*, 1st person singular

Table 1. Inflected forms from the verbal paradigm.

Except for the imperative, each tense possesses seven inflected forms corresponding to grammatical person. Furthermore, there are two infinitives and two gerunds (present and perfect) plus four forms of the participle form, depending on its number/gender variations. The potential therefore exists for up to 140 different forms per verb.

A Spanish verb consists of its stem, tense-mood inflections and person-number inflections. Most of the complexity resides in four factors:

1. Both kinds of inflection (tense-mood and person-number) can sometimes be realized by the same morphological segment;
2. the stem can be realised by different variations, i.e. the same verb can have more than one stem;
3. prefixes and suffixes can be added to the stem; and
4. the verb can be irregular which means that either the stem, the inflections or both are different from the hypothetical regular paradigm of conjugation.

[8] Throughout the paper, the solidus will be used when denoting tense/mood combinations

Of 15,367 verbs, 4,225 are irregular (27.5 %). Moreover, 26.8% of the verbal neologisms in Spanish are irregular [16]. This group of irregular neologisms follow the inflectional patterns of established verbs and conflates genuine paradigmatic irregularity and orthographic issues regarding grapheme realization on stem final consonants among others, shown in Section 4.

Most morphological processing systems are based on combining stems with inflections [19, 7, 12]. By contrast, our verbal paradigm description is based on patterns and transformational rules. Here, the term *rule* is used to denote an alteration that affects the hypothetical regular form of an irregular verb to generate the irregular form that matches with the appropriate irregular conjugation. Such rules are applied to a *pattern* which is the set of inflected forms affected by the irregularity rules (see subsection 4.1) in the verbal conjugation paradigm of the particular verb.

4 System Architecture

The system is composed of two modules, which employ finite state machines. The first one (**Classifier**) is designed to recognize the verb form and extract the information needed for its conjugation or analysis. This information is: (1) the word from which the verb form derives (if there is one) and (2) some formal information on the verb form which is derived via seven finite state automata (regular expressions) which detect wether the verb is regular or irregular based on its ending [16] or, in some cases, from the word that the verb is derived from. This module makes use of two additional purpose-built submodules: one to detect the word from which the verb is derived and another to identify the stress pattern of the verb. These two submodules are used to detect the verb root and to provide information that will later be exploited for its inflection or analysis. When the verb form is irregular, this information will be used to select the irregularity rules and patterns to be applied (see subsection 4.1).

By means of the first module, the verbs are classified into two groups [3]: (a) *regular verbs* and (b) *irregular verbs*. When identified, irregular verbs are further divided into (b.1) the so-called *Magnificent verbs*, *traer* (to bring), *valer* (to be worth), *salir* (to go out), *tener* (to have), *venir* (to come), *poner* (to put), *hacer* (to do), *decir* (to say), *poder* (can), *querer* (to want), *saber* (to know), *caber* (to fit), *andar* (to walk), and their derivations; (b.2) verbs which undergo diphthongization or a vowel replacement in their root; (b.3) verbs which are affected by diacritic rules of irregularity; (b.4) verbs which suffer orthographic changes in their endings; (b.5) verb forms whose root ends in a vowel and will undergo heterogeneous rules of irregularity, and finally; (b.6) the irreducible verbs which are a set of six verbs whose conjugations are stored in memory: the auxiliary verb (*haber*, (to have)), the copulative verbs, *ser* (to be) or *estar* (to be), and the monosyllabic verbs: *ir* (to go) *dar* (to give) and *ver* (to see). Apart from the irreducible verbs, the rest of the verbal paradigm system is based entirely on rules and patterns implemented in Module 2 (**Modeling**).

Module 2 is composed of two conjugation modules. The first module **(2.1 Hypothetical verb form)** conjugates –or analyses– the verb form as if it were

regular by concatenating the root with the corresponding inflections depending on its tense, mood, person and number. The second conjugation module **(2.2 Modifying the hypothetical verb form)** – is composed of several finite state machines. For irregular verbs, it first detects the type of patterns and rules of irregularity that should be applied to the hypothetical verb forms generated by Module 2.1. Next, it applies the selected irregularity rules and patterns to generate the correct irregular paradigm. There are a total of 40 rules and seven patterns, plus two additional ones for the Magnificent verbs.

4.1 Module 2.2: modifying the hypothetical verb form

Patterns: Each pattern is composed of the set of grammatical person, tense, and number forms which are affected by the associated rule. The patterns are correlated with groups of verbs that satisfy a set of formal conditions. The names of the patterns and the characteristics of the inflectional verbs affected by them are stated below:

(1) Pattern **To**: recognizes verbs whose root contains the stressed syllable.
(2) Pattern **Te**: for verbs whose inflection contains the stressed syllable.
(3) Pattern **Dei**: recognizes verbs whose inflections begin with the vowels *e* or *i*.
(4) Pattern **Dao**: recognizes verbs whose inflections begin with the vowels *a* or *o*.
(5) Pattern **Di**: recognizes verbs with a stressed inflection that begins with an unstressed *i*.
(6) Pattern **Dti**: recognizes verbs whose inflections begin with a stressed *i*.
(7) Pattern **Dt-i**: is used to recognize verbs with a stressed inflection that begins with any vowel except *i*.

Depending on the pattern and the formal composition of the verb form, a specific irregularity rule is activated by means of one of the FSTs in Module 2.2: modifying the hypothetical verb form.

To illustrate: pattern **Dei** activates the irregularity modifications (subsection 4.1) which always affect third person singular and first and third person plural forms of the present tense/imperative, all the person forms of the present tense/subjunctive and the first person singular of the preterite perfect simple tense/indicative. For example, the form *escenifique* from *escenificar* (to stage) substitutes the letter *c* by *qu* in the first person singular present tense/subjunctive form.

Similarly, the irregularity rules (see subsection 4.1) activated by the pattern **Di** will only affect the gerund, the third person singular and the first person plural forms of the preterite perfect simple tense/indicative plus all the grammatical person forms of the preterite imperfect tense/subjunctive and the future tense/subjunctive. To illustrate, the verb form *cayere* from verb *caer* (to fall) adds a *y* between its root and the inflections in all person forms of the preterite imperfect/subjunctive and the future/subjunctive tenses/moods.

The Magnificent verbs are recognized using two specific patterns:

(8) Pattern **Fc**: for all the grammatical person forms of future and conditional tenses/indicative moods.

(9) Pattern **í4**: allows recognition of verbs for all person forms belonging to preterite perfect simple tense/indicative mood and preterite imperfect/subjunctive and the future/subjunctive tenses/moods.

Irregularity Transformational Rules: Finally, Module 2.2 applies the pertinent irregularity modifications over the hypothetical regular forms generated by Module 2.1. in order to generate the corresponding irregular verb form.

The rules perform one of the following three types of alteration:

- **substitution**, (e.g. *z* is substituted by *c* in pattern **Dei**, to derive the first person singular present tense/subjunctive inflected form *trace* from *trazar* (to trace));
- **addition**, (e.g. *z* is added in the root for verb forms recognized using the pattern **Dao**, as illustrated when the first person singular present tense/indicative form *conozco* is derived from *conocer* (to know));
- **deletion**, (e.g. the vowel *i* is removed from the inflections of verbs recognized by means of the **Di** pattern, as illustrated when the first person singular present tense/indicative form *taño* is derived from *tañer* (to strum)).

Overall, 40 irregularity rules have been implemented. They are divided into five groups:

(1) **Consonantal orthographic transduction rules**: These comprise 9 FSTs which modify the verb in order to ensure that the derived form obeys Spanish orthographic conventions. These rules are activated for verbs recognized using the patterns **Dei**, **Dao** and **Di** (e.g. one rule of this type enables the first person singular, present tense/indicative form *sigo* to be derived from *seguir* (to follow), when it is activated by the pattern **Dao**).
(2) **Diacritic transduction rules**: Comprised by 2 FSTs activated by the pattern **To** (The processing that they perform is illustrated by the derivation of the first person singular, present tense/indicative form *vacío* from *vaciar* (to empty)).
(3) **Root vowel transduction rules**: Comprised by 8 FSTs that operate on the root vowel, which can be either diphthongized or replaced by another vowel. These irregularity rules are activated by patterns **To** and **Dti** (e.g. when the first person singular, present tense/indicative form *sirvo* is derived from *servir* (to serve), having been activated by the pattern **Dti**).
(4) **Vowel root ending transduction rules**: Comprised of 8 FSTs which apply heterogeneous transduction rules affecting those verbs whose infinitive form root ends in a vowel. The use of these rules is illustrated by the derivation of *oyes* from *oír* (to hear) by addition of the letter *y* after the root, having been activated by the pattern **Te**.
(5) **Specific Magnificent verbs transduction rules**: Comprising 13 FSTs activated by the patterns **Fc**, **í4**, **Dao** and **To**. To illustrate, the root of the verb *tener* (to have) is changed (when the rule is activated by the pattern **í4**). *(Tuve)*, is modified by adding the letter *g* after its root (when the rule is activated by the pattern **Dao**) and *(tengo)* is modified by addition of *d* after the root in the verb forms recognized by the pattern **Fc** *(tendré)*.

The FSTs exploited in Module 2.2 are arranged in a cascade as their order of application is important, given that most of the irregular verbs activate several rules. For instance, *dormir* (to sleep) undergoes substitution of its root vowel *o* by *u* when recognized by pattern **Dti** (firstly, the second person plural of present tense/subjunctive form *durmáis*, is derived. This is followed by diphthongization of the root vowel when it is recognized by the pattern **To** to derive the first person singular of present tense/indicative form *duermo*.

5 Comparative Evaluation

A comparative evaluation of the system was carried out against seven Spanish conjugators that are available online. They are:

1. Royal Spanish Academy Conjugator: http://buscon.rae.es/draeI/.
2. Reverso conjugator: http://conjugador.reverso.net/conjugacion-espanol.html.
3. WordReference Spanish Verb Conjugator: http://www.wordreference.com/conj/EsVerbs.asp.
4. University of Oviedo conjugator: http://www6.uniovi.es/dic/conjuga.html.
5. The conjugator developed by Grupo de Estructuras de Datos y Lingüística Computational from University of Las Palmas de Gran Canaria: http://www.gedlc.ulpgc.es/investigacion/scogeme02/flexver.htm.
6. SpanishDict Verb Conjugator: http://www.spanishdict.com/conjugate/.
7. Verbix Spanish Verb Conjugator v.2.0: http://www.verbix.com/languages/spanish.shtml.

Please notice the comparison between these results should be done with caution since there is no reason to assume that the other conjugators are aiming to address the same task, specifically, the conjugation of verbal neologisms.

A list containing 40 heterogeneous verb forms (inflectional forms as well as infinitives) was tested against each conjugator. The verb forms used in the evaluation were carefully selected on account of their difficulty. They can be classified into five *ad hoc* categories: (1) regular and irregular verb neologisms[9], formed by concatenating a prefix to an existing verb: *autodestruir* (to self destroy); or (2) verb neologisms formed from words which are not verbs: *googlear* (to google); (3) verbs with multiple conjugation: *roer* (to gnaw) which, for example, can be conjugated as *roo*, *roigo* or *royo* in its first person singular form in present tense/indicative mood); (4) verbs with double meanings whose paradigm of conjugation differs depending on the meaning: *acostar* (*acuesto*, to put in bed; *acosto*, to reach the coast) (Table 2); and (5) ambiguous inflected forms (Table 3). Of the 40 verb forms, 10 belong to class 1, 10 to class 2, 6 instances belong to classes 3 and 6 to class 5. 8 ambiguous examples belong to class 5.

Table 2 presents which systems are able to generate the different kinds of verbal paradigms, while Table 3 shows which systems analyze inflected verb forms

[9] The neologisms chosen for the evaluation are not present in MICV-DB.

System	Conjugation	1 Prefix neologisms	2 New word neologisms	3 Multiple conjugation	4 Double meaning
Conjugator 1	yes	no	no	yes	yes (see text)
Conjugator 2	yes	no (see text)	no	no	no
Conjugator 3	yes	no	no	yes	no
Conjugator 4	yes	no	no	yes	no
Conjugator 5	yes	yes	no	yes	no
Conjugator 6	yes	no	no	no	no
Conjugator 7	yes	yes	yes	yes	no
Onoma	yes	yes	yes	yes	yes

Table 2. Comparative evaluation: generation of verbal paradigms.

and ambiguous inflected forms. Table 4 presents the accuracy of the conjugation or the analysis of 40 verb forms in the systems.

Conjugator 1 (in Table 2) does present the two different conjugations of a verb with double meanings, although it does not state which type of verbal paradigm corresponds to which meaning, as our system does. *Onoma* offers the user the opportunity to first choose the appropriate meaning and then displays the verb paradigm depending on the user's choice. Conjugator 2 does conjugate some verb neologisms formed with prefixes although it does not cover all cases (e.g. *cohacer* (to do at the same time)).

Only half of the tested conjugators (including *Onoma*) analyze inflected verb forms (see Table 3) and ambiguous verb forms (5) were used to test this type of analysis. For instance, *sé* can either be the first person singular form indicating the present tense/indicative mood of the verb *saber* (to know), or the second person singular present tense/imperative form of the verb *ser* (to be).

System	Analysis 5	Ambiguous verb forms analysis
Conjugator 1	no	no
Conjugator 2	yes	no
Conjugator 3	yes	yes
Conjugator 4	no	no
Conjugator 5	yes	yes
Conjugator 6	no	no
Conjugator 7	no	no
Onoma	yes	yes

Table 3. Comparative evaluation: analysis of inflected verb forms.

As can be inferred from the evaluation presented, no other existing online conjugation system is as extensive in its functionality and the range of features employed. This is particularly evident in its ability to identify and analyze am-

System	Conjugation accuracy: neologisms and registered verbs	Analysis accuracy: registered verbs
Conjugator 1	37.5%	none
Conjugator 2	25.0%	37.5%
Conjugator 3	31.2%	87.5%
Conjugator 4	31.2%	none
Conjugator 5	50.0%	100%
Conjugator 6	15.6%	none
Conjugator 7	81.2%	none
Onoma	100%	87,5%

Table 4. Comparative evaluation: accuracy of conjugation and analysis.

biguous inflected forms, verb neologisms and to deal with verbs that have double meanings and therefore, double conjugations.

Nevertheless, our system does not conjugate six outdated verbs (e.g. *far* (to do), *caler* (to be necessary), etc.) as, to our knowledge, such paradigms have been largely unexplored, though two conjugators (2 and 7) do present the possible verbal paradigm for this small group of verbs. Given that they are not used in contemporary Spanish, their treatment is considered beyond the scope of the present paper.

On this data set, *Onoma* is able to conjugate verbal paradigms with 100% accuracy, while its accuracy in analysing verb forms is 87,5%. Onoma, as well as displaying the correct verb paradigms in its analysis of all registered verbs sometimes includes paradigms of verbs that may possibly occur in Spanish, but are not registered in existing dictionaries. When paradigms of non-registered verbs are included in its analyses of a verb, this is considered an error, regardless of whether or not the rest of the analysis is correct. While this strict approach to evaluation adversely affects the performance level reported for *Onoma*, it allows a feasible comparison to be made with those systems that do not treat neologisms. Overall, it can be concluded that *Onoma* compares favorably with the other conjugators in terms of the accuracy of analysis and conjugation.

6 Final Remarks

In this paper we have presented *Onoma*, a system which conjugates Spanish verbs, including neologisms. *Onoma's* linguistically motivated model for verb paradigms is novel and has great potential for pedagogic applications in teaching the intricacies of the Spanish verb conjugation system.

As the *Onoma* transducers are implemented on a database management system, they are simple to modify independently of the rest of the software. In future work, we plan to integrate the *Onoma* algorithm into a general Spanish morphological processor to treat the rest of the open-class lexical categories.

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