Causes and consequences of complexity in Portuguese verbal paradigms

Olivier Bonami\textsuperscript{1} & Ana R. Luís\textsuperscript{2}

\textsuperscript{1}U. Paris-Sorbonne, IUF, Laboratoire de Linguistique Formelle
\textsuperscript{2}U. de Coimbra, CELGA

Ninth Mediterranean Morphology Meeting, Dubrovnik, September 2013
## Introduction

- Implicative structure of paradigms (Wurzel, 1984): the form filling a cell in the paradigm provides information on the forms filling other cells.

<table>
<thead>
<tr>
<th></th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FICAR</td>
<td>fiku</td>
<td>fike</td>
<td>fike</td>
<td>fik'emsp</td>
<td>fik'ais</td>
<td>fik'ẽũ</td>
</tr>
<tr>
<td>VIVER</td>
<td>v'ivu</td>
<td>v'ivəʃ</td>
<td>v'ivə</td>
<td>viv'emus</td>
<td>viv'ais</td>
<td>vivẽĩ</td>
</tr>
<tr>
<td>IMPRIMIR</td>
<td>iprimu</td>
<td>ipriməʃ</td>
<td>iprimə</td>
<td>iprim'imus</td>
<td>iprim'iʃ</td>
<td>iprimẽĩ</td>
</tr>
</tbody>
</table>

Indicative present of 3 European Portuguese fully regular verbs

- Two basic questions about implicative structure:
  - How much information is provided?
  - What aspects of the form provide that information?
  - In some cases, segmentable morphs
  - In other cases, other types of systematic covariation
**Instrumented Item and Pattern morphology**

- **Item and pattern (IPa) morphology (Blevins, to appear):**
  - Focuses on patterns of alternation among forms filling cells in a paradigm
  - Not morph-centric: while patterns may consist of morph insertion/deletion/substitution, this is not necessary to their identification and use.

- **Quantitative IPa**
  - Heavy use of quantitative methods, including information-theoretic measures
    - (Ackerman et al., 2009) and later work, e.g. Sims (2010); Bonami et al. (2011, 2012); Ackerman and Malouf (in press); Blevins (to appear)

- **Instrumented IPa:**
  - Based on large scale inflected lexica
  - Automatic inference and analysis of patterns using simple, opportunistic methods
  - Focus on coverage and precision of empirical generalizations
Structure

1. Introduction

2. Finding patterns

3. Using patterns
   - Induction of inflection classes
   - Partitioning paradigms
   - Gradient predictiveness

4. Causes of low predictiveness
   - Theme vowels
   - Prethematic vowels
   - Irregulars
   - Joint predictiveness

5. Conclusions
The dataset

- Full paradigms of the 2000 most frequent verbs in the CETEMPúblico corpus (Santos and Rocha, 2001)
- Fully transcribed in IPA on the basis of the U. of Coimbra pronunciation dictionary (Veiga et al., 2012)
  - Unique transcription for each paradigm cell of each lexeme, which entails a certain amount of idealization.
  - The transcription corresponds most closely to slow, careful speech in central Portugal.
Finding patterns
The general problem

- A basic building block for the kind of investigation at hand is a method for identifying patterns of alternation.
- Which method one uses has dramatic effects on the ensuing analyses.
- A general, language-independent method is hard to define and computationally expensive.
  - For a large (>1000) set of pairs of forms, find the smallest set of subsequential finite-state transducers relating these pairs.
- Opportunistic strategy: we use prior knowledge of the system to decide on a reasonably simple method that we suspect won't miss important patterns.
- For Portuguese: We know that inflection is suffixal, but that the last vowel of the stem (the prethematic vowel) often alternates.
An opportunistic solution

- Over 2000 pairs of cells:
  1. Identify ‘quasi-suffixes’: what remains if one drops the longest identical initial substrings
  2. Fuse patterns with covarying central consonant cluster
  3. Record of common phonotactic properties of the nonalternating parts, using a Minimal Generalization strategy (Albright, 2002)

<table>
<thead>
<tr>
<th>lexeme</th>
<th>PRS.1SG</th>
<th>PRS.1PL</th>
<th>step 1</th>
<th>step 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FICAR</td>
<td>fiˈku</td>
<td>fiˈkɐmuʃ</td>
<td>Xu ⇔ Xɐmuʃ</td>
<td>Xu ⇔ Xɐmuʃ</td>
</tr>
<tr>
<td>PASSAR</td>
<td>paˈasu</td>
<td>paˈesˈemusʃ</td>
<td>Xasu ⇔ Xesɐmuʃ</td>
<td>Xa Yu ⇔ Xe Yemusʃ</td>
</tr>
<tr>
<td>PAGAR</td>
<td>paˈagu</td>
<td>paˈegˈemusʃ</td>
<td>Xagu ⇔ Xegɐmuʃ</td>
<td>Xa Yu ⇔ Xe Yemusʃ</td>
</tr>
<tr>
<td>CHEGAR</td>
<td>jeˈgu</td>
<td>jeˈegˈemusʃ</td>
<td>Xegu ⇔ Xegɐmuʃ</td>
<td>Xe Yu ⇔ Xe Yemusʃ</td>
</tr>
<tr>
<td>MOSTRAR</td>
<td>mˈʃtru</td>
<td>mˈʃtɾɐmuʃ</td>
<td>Xɔ Yu ⇔ Xu Yemusʃ</td>
<td>Xɔ Yu ⇔ Xu Yemusʃ</td>
</tr>
</tbody>
</table>

- Sample phonotactic condition:
  \[ XC_1 e C_2 u \rightleftharpoons XC_1 e C_2 \text{emusʃ}, \]
  where \( X \) is any sequence, \( C_1 : [+\text{cons}, −\text{voc}] \), \( C_2 : [+\text{cons}, −\text{voc}, −\text{lat}] \)
Using patterns
Using patterns

Induction of inflection classes
Inflection classes as vectors of patterns

- Each lexeme is now characterized by the vector of patterns it uses to relate each pair of cells in the paradigm

<table>
<thead>
<tr>
<th>lexeme</th>
<th>(1\text{SG}, 2\text{SG})</th>
<th>(1\text{SG}, 3\text{SG})</th>
<th>(1\text{SG}, 1\text{PL})</th>
<th>(1\text{SG}, 2\text{PL})</th>
<th>(1\text{SG}, 3\text{PL})</th>
<th>(2\text{SG}, 3\text{SG})</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>ficar</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_em\u)</td>
<td>(X_u \equiv X_ei)</td>
<td>(X_u \equiv X_e\u)</td>
<td>(X_e \equiv X_e)</td>
<td>...</td>
</tr>
<tr>
<td>viver</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_em\u)</td>
<td>(X_u \equiv X_ei)</td>
<td>(X_u \equiv X_e\i)</td>
<td>(X_e \equiv X_e)</td>
<td>...</td>
</tr>
<tr>
<td>imprimir</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_e)</td>
<td>(X_u \equiv X_im\u)</td>
<td>(X_u \equiv X_i)</td>
<td>(X_u \equiv X_e\i)</td>
<td>(X_e \equiv X_e)</td>
<td>...</td>
</tr>
</tbody>
</table>

- Gives us a very fine-grained definition of inflection class: if two lexemes have the exact same vector of patterns, then they definitely belong to the same inflection class.
- Gives us a very simple notion of distance between inflection classes: the Hamming distance between the two vectors
  - The number of pairs of cells for which the two vectors differ
- This distance can then be used with off-the-shelf clustering algorithms to produce groupings in superclasses
Dendrogram computed from the Hamming distance over 2000 verbs by Neighbor-joining (Saitou and Nei, 1987) Colors indicate theme vowels.
The virtues of the method

- We get a classification of overall inflection patterns that is
  - Entirely automated
  - Not dependent on fine decisions of segmentation
  - Easily criticizable

- Similar in spirit (but not in execution) to Brown and Evans (2012)
  - Where Brown and Evans (2012) use compression distance, we use distance between (vectors of) patterns
    - Two lexemes with identical inflection have a distance of zero
  - Where Brown and Evans (2012) use a sophisticated clustering method, we use a very simple one
    - Easier to understand what the clustering method really does
Using patterns
Partitioning paradigms
Fully interpretable cells

- Two patterns relating cells $c$ and $c'$ are mutually exclusive if they impose incompatible constraints on both $c$ and $c'$.

<table>
<thead>
<tr>
<th>PRS.1SG $\Leftrightarrow$ PRS.1PL</th>
<th>PRS.3SG $\Leftrightarrow$ PRS.2PL</th>
<th>PRS.3SG $\Leftrightarrow$ PRS.3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_u \Leftrightarrow X_emuʃ$</td>
<td>$X_e \Leftrightarrow X_aiʃ$</td>
<td>$X_e \Leftrightarrow X_eêmɨŋ$</td>
</tr>
<tr>
<td>$X_u \Leftrightarrow X_imuʃ$</td>
<td>$X_aCaɨ \Leftrightarrow X_eCaɨʃ$</td>
<td>$X_e \Leftrightarrow X_eêmĩ$</td>
</tr>
<tr>
<td>not exclusive</td>
<td>not exclusive</td>
<td>exclusive</td>
</tr>
</tbody>
</table>

- NB: the existence of non-exclusive patterns sometimes leads to genuine ambiguity, even given perfect knowledge of the lexicon

<table>
<thead>
<tr>
<th>lexeme</th>
<th>PRS.1SG</th>
<th>PRS.1PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>girar</td>
<td>ʒiru</td>
<td>ʒirəmuʃ</td>
</tr>
<tr>
<td>gerir</td>
<td>ʒiru</td>
<td>ʒərimuʃ</td>
</tr>
</tbody>
</table>

- If all patterns used to relate those two cells are pairwise mutually exclusive, then these two cells are fully interpretable.
Partitioning the paradigm

- We can now partition the paradigm into zones of perfect interpredictibility (Ackerman et al.'s (2009) ‘alliances of forms’)

<table>
<thead>
<tr>
<th></th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRS.IND</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PRS.IPVF.IND</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PST.IPVF.IND</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PST.PRF.IND</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>FUT.IND</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>COND</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PRS.SBJV</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PST.SBJV</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>FUT.SBJV</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>IMP</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>INF.CNJ</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>INF</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>GER</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>M.SG</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>PST.PTCP</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>M.PL</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>F.SG</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>F.PL</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
Discussion

- The partition highlights morphomic patterns
  - See Bonami and Boyé (to appear) for systematic discussion of differences
- However here predictibility is defined purely on the basis of full forms,
  - Does not presuppose any disputable decision on segmentation into stems and exponents (Boyé, 2000; Spencer, 2012; Stump and Finkel, 2013)
- A practical consequence of the identification of a partition is that we can focus on a distillation of the paradigm (Stump and Finkel, 2013): just pick one cell from each cell in the partition, and forget about the others.
Using patterns
Gradient predictiveness
Gradient predictiveness

- Predictiveness is clearly a gradient property: some predictions are categorical, others are very reliable, others still have little reliability.

- Capturing this gradience motivates the use of conditional entropy to model implicative relations in paradigms (Ackerman et al., 2009).
Measuring predictiveness

To evaluate how $c$ predicts $c'$, we need to identify, for each possible form filling $c$, the set of patterns that could relate $c$ to $c'$.

<table>
<thead>
<tr>
<th>PRS.1SG</th>
<th>PRS.1.SG $\rightleftarrows$ SBJV.3SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>ends in $\varepsilon u$</td>
<td>$\varepsilon u \rightleftarrows \varepsilon e$</td>
</tr>
<tr>
<td>ends in $u$ but neither in $\varepsilon u$ nor in $aizu$</td>
<td>$\varepsilon u \rightleftarrows \varepsilon e$</td>
</tr>
<tr>
<td>ends in $aizu$</td>
<td>$\varepsilon u \rightleftarrows \varepsilon e$</td>
</tr>
<tr>
<td>ends in $o$</td>
<td>$o \rightleftarrows eiz$</td>
</tr>
<tr>
<td>ends in $ai$</td>
<td>$a \rightleftarrows eiz$</td>
</tr>
</tbody>
</table>

Distribution of patterns relating PRS.1SG to SBJV.3SG for 1996 verbs
Measuring predictiveness

- To quantify predictiveness, we want to evaluate the likelihood of each possibility.
  - Approximate probabilities on the basis of type frequency
  - Use conditional entropy of a pattern as a measure of predictiveness
  - \( H(\text{pattern} \mid \text{PRS.1SG}) \approx -\frac{1986}{1996}(0.76 \log_2 0.76 + 0.24 \log_2 0.24) \approx 0.7855 \)

<table>
<thead>
<tr>
<th>freq.</th>
<th>PRS.1SG</th>
<th>PRS.1.SG ⇔ SBJV.3SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>ends in ĕɾu</td>
<td>( X_\epsilon u \Leftrightarrow X_\epsilon i e r e )</td>
</tr>
<tr>
<td>1986</td>
<td>ends in u but neither in ĕɾu nor in ēɾiʒu</td>
<td>( X_u \Leftrightarrow X_\epsilon )</td>
</tr>
<tr>
<td>5</td>
<td>ends in ēɾiʒu</td>
<td>( X_\epsilon i \z u \Leftrightarrow X_\epsilon \z e )</td>
</tr>
<tr>
<td>2</td>
<td>ends in o</td>
<td>( X_o \Leftrightarrow X_\epsilon i z e )</td>
</tr>
<tr>
<td>1</td>
<td>ends in ēi</td>
<td>( X_\epsilon i \Leftrightarrow X_\epsilon a z e )</td>
</tr>
</tbody>
</table>

Distribution of patterns relating PRS.1SG to SBJV.3SG for 1996 verbs
Using patterns
Gradient predictiveness

Raw results

- Systematic application of this method to a distillation of the paradigm:

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>PRS.IND.1SG</th>
<th>PRS.IND.3SG</th>
<th>PRS.IND.2PL</th>
<th>PRS.IND.3PL</th>
<th>PST.IPFV.IND.3SG</th>
<th>PST.PFV.IND.1SG</th>
<th>PST.PFV.IND.3SG</th>
<th>PST.PTCP</th>
<th>FUT.IND.3SG</th>
<th>PRS.SBJV.3SG</th>
<th>PRS.SBJV.2PL</th>
<th>PST.PTCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>INF</td>
<td>0</td>
<td>0.3427</td>
<td>0.3032</td>
<td>0.0541</td>
<td>0.3706</td>
<td>0.0163</td>
<td>0.0163</td>
<td>0.0263</td>
<td>0</td>
<td>0.3427</td>
<td>0.0295</td>
<td>0.0121</td>
<td></td>
</tr>
<tr>
<td>PRS.IND.1SG</td>
<td>0.6990</td>
<td>0.6366</td>
<td>0.6990</td>
<td>0.6594</td>
<td>0.6832</td>
<td>0.6761</td>
<td>0.6990</td>
<td>0.6990</td>
<td>0.7855</td>
<td>0.6821</td>
<td>0.6678</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRS.IND.3SG</td>
<td>0.2044</td>
<td>0.0819</td>
<td>0</td>
<td>0.2044</td>
<td>0.0041</td>
<td>0.0856</td>
<td>0.0856</td>
<td>0.2042</td>
<td>0.2382</td>
<td>0.0848</td>
<td>0.1461</td>
<td>0.0837</td>
<td></td>
</tr>
<tr>
<td>PRS.IND.2PL</td>
<td>0.0316</td>
<td>0.3422</td>
<td>0.3574</td>
<td>0</td>
<td>0.3605</td>
<td>0.0316</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.3422</td>
<td>0.0307</td>
<td>0.0311</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRS.IND.3PL</td>
<td>0.2124</td>
<td>0.1012</td>
<td>0.0059</td>
<td>0.2124</td>
<td>0</td>
<td>0.0859</td>
<td>0.0856</td>
<td>0.2084</td>
<td>0.2102</td>
<td>0.0936</td>
<td>0.1469</td>
<td>0.0838</td>
<td></td>
</tr>
<tr>
<td>PST.IPFV.IND.3SG</td>
<td>0.2184</td>
<td>0.4136</td>
<td>0.3755</td>
<td>0.2300</td>
<td>0.3812</td>
<td>0</td>
<td>0</td>
<td>0.2120</td>
<td>0.2011</td>
<td>0.4136</td>
<td>0.0609</td>
<td>0.0094</td>
<td></td>
</tr>
<tr>
<td>PST.PFV.IND.1SG</td>
<td>0.2594</td>
<td>0.4102</td>
<td>0.3720</td>
<td>0.2525</td>
<td>0.3773</td>
<td>0.0471</td>
<td>0</td>
<td>0.2592</td>
<td>0.2464</td>
<td>0.4102</td>
<td>0.1062</td>
<td>0.0563</td>
<td></td>
</tr>
<tr>
<td>PST.PFV.IND.3SG</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.3498</td>
<td>0.0136</td>
<td>0.3521</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.0016</td>
<td>0.0030</td>
<td></td>
</tr>
<tr>
<td>FUT.IND.3SG</td>
<td>0.0333</td>
<td>0.3441</td>
<td>0.3776</td>
<td>0.0650</td>
<td>0.3699</td>
<td>0.0533</td>
<td>0.0245</td>
<td>0.0345</td>
<td>0</td>
<td>0.3441</td>
<td>0.0444</td>
<td>0.0203</td>
<td></td>
</tr>
<tr>
<td>PRS.SBJV.3SG</td>
<td>0.1894</td>
<td>0.0000</td>
<td>0.0657</td>
<td>0.1894</td>
<td>0.0632</td>
<td>0.1350</td>
<td>0.1350</td>
<td>0.1894</td>
<td>0</td>
<td>0.0917</td>
<td>0.1332</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRS.SBJV.2PL</td>
<td>0.2049</td>
<td>0.3912</td>
<td>0.4138</td>
<td>0.2049</td>
<td>0.4187</td>
<td>0.0483</td>
<td>0.0483</td>
<td>0.2049</td>
<td>0.1836</td>
<td>0.3912</td>
<td>0.0483</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PST.PTCP</td>
<td>0.2109</td>
<td>0.4218</td>
<td>0.3431</td>
<td>0.2133</td>
<td>0.3806</td>
<td>0.0191</td>
<td>0.0191</td>
<td>0.2209</td>
<td>0.1970</td>
<td>0.4218</td>
<td>0.0657</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- We can now look for patterns in this table and look for causes of particular entropy values in the log
Using patterns    Gradient predictiveness

***************************************
PresConj3 ==> PresIndic1
***************************************

Inferring rules...

\[ \varepsilon \rightarrow u / X[p,t,k,b,d,g,f,s,j,v,z,3,m,n,p,l,\lambda,l,\sim,r,i,i,\hat{e},e,\varepsilon,\varepsilon,o,\varepsilon,u,\ddot{i},\ddot{e},\ddot{o},\ddot{u}] \] # 1516

\[ e \rightarrow u / X[p,t,k,b,d,g,f,s,j,v,z,3,m,n,p,l,\lambda,l,\sim,r,i,i,\hat{e},e,\varepsilon,\varepsilon,o,\varepsilon,u,\ddot{i},\ddot{e},\ddot{o},\ddot{u}] \] # 470

\[ e\text{i}\text{e} \rightarrow \varepsilon \varepsilon u / Xk \] # 2

\[ e\hat{z}e \rightarrow e\hat{i}z\varepsilon / Xv \] # 5

\[ e\hat{i}\hat{z}e \rightarrow o / X[t,s] \] # 2

\[ a\hat{z}e \rightarrow e\hat{i} / \] # 1

done.

class 1 ( \( \text{r}\hat{a}\text{k}\varepsilon\text{i}\varepsilon\rightarrow \text{r}\varepsilon\varepsilon\varepsilon u \) ): 2 members

\[ e \rightarrow u / X[p,t,k,b,d,g,f,s,j,v,z,3,m,n,p,l,\lambda,l,\sim,r,i,i,\hat{e},e,\varepsilon,\varepsilon,o,\varepsilon,u,\ddot{i},\ddot{e},\ddot{o},\ddot{u}] \] # : 0

\[ e\text{i}\text{e} \rightarrow \varepsilon \varepsilon u / Xk \] # : 2 (requerer, etc.)

local conditional entropy: -0.0

-----

class 2 ( a\hat{z}e \rightarrow e\hat{i} ): 1 members

\[ e \rightarrow u / X[p,t,k,b,d,g,f,s,j,v,z,3,m,n,p,l,\lambda,l,\sim,r,i,i,\hat{e},e,\varepsilon,\varepsilon,o,\varepsilon,u,\ddot{i},\ddot{e},\ddot{o},\ddot{u}] \] # : 0

\[ a\hat{z}e \rightarrow e\hat{i} / \] # : 1 (haver, etc.)

local conditional entropy: -0.0

-----

class 3 ( m\varepsilon\nu\varepsilon\varepsilon\varepsilon\varepsilon z\zeta \rightarrow m\varepsilon\nu\varepsilon\varepsilon\varepsilon\varepsilon z\zeta u ): 1516 members

\[ \varepsilon \rightarrow u / X[p,t,k,b,d,g,f,s,j,v,z,3,m,n,p,l,\lambda,l,\sim,r,i,i,\hat{e},e,\varepsilon,\varepsilon,o,\varepsilon,u,\ddot{i},\ddot{e},\ddot{o},\ddot{u}] \] # : 1516 (menos)

local conditional entropy: -0.0

-----

Bonami & Luís (Paris/Coimbra)
Causes of low predictiveness
Theme vowels

- The fate of Latin theme vowels in Portuguese is variable:
  - In the PRS.1SG, complete loss of theme vowel distinctions
  - Many paradigm cells carry some suffixal material coding a two-way distinction between first and other conjugations
  - Still other cells keep a 3 way distinction, although that does not entail that the vowels are unaltered

- Consequences:
  - The PRS.1SG is a bad predictor of all other paradigm cells
  - Cells making a two way distinction are bad predictors of cells making a three way distinction

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FICAR</td>
<td>fik'ar</td>
<td>fiku</td>
<td>fikeʃ</td>
<td>fike</td>
<td>fikemuş</td>
<td>fik'aiʃ</td>
<td>fik'eũ</td>
</tr>
<tr>
<td>VIVER</td>
<td>viver</td>
<td>v'ivu</td>
<td>v'iveʃ</td>
<td>v'ive</td>
<td>v'iveuş</td>
<td>v'iveiʃ</td>
<td>v'iveĩ</td>
</tr>
<tr>
<td>IMPRIMIR</td>
<td>Ɦprim'ir</td>
<td>Ɦprim'imu</td>
<td>Ɦprim'eʃ</td>
<td>Ɦprim'e</td>
<td>Ɦprim'euş</td>
<td>Ɦprim'eiʃ</td>
<td>Ɦprim'eĩ</td>
</tr>
</tbody>
</table>
### Theme vowels

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>PRS.IND.1SG</th>
<th>PRS.IND.3SG</th>
<th>PRS.IND.2PL</th>
<th>PRS.IND.3PL</th>
<th>PST.IPFV.IND.3SG</th>
<th>PST.PFV.IND.1SG</th>
<th>PST.PFV.IND.3SG</th>
<th>FUT.IND.3SG</th>
<th>PRS.SBJV.3SG</th>
<th>PRS.SBJV.2PL</th>
<th>PST.PTCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>INF</td>
<td>0</td>
<td>0.3427</td>
<td>0.3032</td>
<td>0.0541</td>
<td>0.3706</td>
<td>0.0163</td>
<td>0.0163</td>
<td>0.0263</td>
<td>0</td>
<td>0.3427</td>
<td>0.0295</td>
<td>0.0121</td>
</tr>
<tr>
<td>PRS.IND.1SG</td>
<td>0.6990</td>
<td>0</td>
<td>0.6366</td>
<td>0.6990</td>
<td>0.6594</td>
<td>0.6832</td>
<td>0.6761</td>
<td>0.6990</td>
<td>0.6990</td>
<td>0.7855</td>
<td>0.6821</td>
<td>0.6678</td>
</tr>
<tr>
<td>PRS.IND.3SG</td>
<td>0.2044</td>
<td>0.0819</td>
<td>0</td>
<td>0.2044</td>
<td>0.0041</td>
<td>0.0856</td>
<td>0.0856</td>
<td>0.2042</td>
<td>0.2382</td>
<td>0.0848</td>
<td>0.1461</td>
<td>0.0837</td>
</tr>
<tr>
<td>PRS.IND.2PL</td>
<td>0.0316</td>
<td>0.3422</td>
<td>0.3574</td>
<td>0</td>
<td>0.3605</td>
<td>0.0316</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.3422</td>
<td>0.0307</td>
<td>0.0311</td>
<td></td>
</tr>
<tr>
<td>PRS.IND.3PL</td>
<td>0.2124</td>
<td>0.1012</td>
<td>0.0059</td>
<td>0.2124</td>
<td>0</td>
<td>0.0859</td>
<td>0.0856</td>
<td>0.2084</td>
<td>0.2102</td>
<td>0.0936</td>
<td>0.1469</td>
<td>0.0838</td>
</tr>
<tr>
<td>PST.IPFV.IND.3SG</td>
<td>0.2184</td>
<td>0.4136</td>
<td>0.3755</td>
<td>0.2300</td>
<td>0.3812</td>
<td>0</td>
<td>0.2120</td>
<td>0.2011</td>
<td>0.4136</td>
<td>0.0609</td>
<td>0.0094</td>
<td></td>
</tr>
<tr>
<td>PST.PFV.IND.1SG</td>
<td>0.2594</td>
<td>0.4102</td>
<td>0.3720</td>
<td>0.2525</td>
<td>0.3773</td>
<td>0.0471</td>
<td>0</td>
<td>0.2592</td>
<td>0.2464</td>
<td>0.4102</td>
<td>0.1062</td>
<td>0.0563</td>
</tr>
<tr>
<td>PST.PFV.IND.3SG</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.3498</td>
<td>0.0136</td>
<td>0.3521</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.0016</td>
<td>0.0030</td>
</tr>
<tr>
<td>FUT.IND.3SG</td>
<td>0.0333</td>
<td>0.3441</td>
<td>0.3776</td>
<td>0.0650</td>
<td>0.3699</td>
<td>0.0533</td>
<td>0.0245</td>
<td>0.0345</td>
<td>0</td>
<td>0.3441</td>
<td>0.0444</td>
<td>0.0203</td>
</tr>
<tr>
<td>PRS.SBJV.3SG</td>
<td>0.1894</td>
<td>0.0000</td>
<td>0.0657</td>
<td>0.1894</td>
<td>0.0632</td>
<td>0.1350</td>
<td>0.1350</td>
<td>0.1894</td>
<td>0.1894</td>
<td>0</td>
<td>0.0917</td>
<td>0.1332</td>
</tr>
<tr>
<td>PRS.SBJV.2PL</td>
<td>0.2049</td>
<td>0.3912</td>
<td>0.4138</td>
<td>0.2049</td>
<td>0.4187</td>
<td>0.0483</td>
<td>0.0483</td>
<td>0.2049</td>
<td>0.1836</td>
<td>0.3912</td>
<td>0</td>
<td>0.0483</td>
</tr>
<tr>
<td>PST.PTCP</td>
<td>0.2109</td>
<td>0.4218</td>
<td>0.3431</td>
<td>0.2133</td>
<td>0.3806</td>
<td>0.0191</td>
<td>0.0191</td>
<td>0.2209</td>
<td>0.1970</td>
<td>0.4218</td>
<td>0.0657</td>
<td>0</td>
</tr>
</tbody>
</table>

- The entropy associated with the prediction of 3-way distinctions from 2-way distinction is not very high

- Explanation: 1st conjugation verbs make up 76% of our data
Prethematic vowels

- Portuguese oral vowels exhibit stress-conditioned alternations
- While some cells have a stressed prethematic vowel, in other cells stress falls elsewhere, typically on the theme vowel.
- This causes uncertainty when trying to predict stressed vowels from unstressed ones.
Prethematic vowels

- The difficulty of predicting the quality of stressed prethematic vowels is the second highest contributor of entropy

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>PRS.IND.1SG</th>
<th>PRS.IND.3SG</th>
<th>PRS.IND.2PL</th>
<th>PRS.IND.3PL</th>
<th>PST.IPFV.IND.3SG</th>
<th>PST.PFV.IND.1SG</th>
<th>PST.PFV.IND.3SG</th>
<th>FUT.IND.3SG</th>
<th>PRS.SBJV.3SG</th>
<th>PRS.SBJV.2PL</th>
<th>PST.PTCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>INF</td>
<td>0.3427</td>
<td>0.3032</td>
<td>0.0541</td>
<td>0.3706</td>
<td>0.0163</td>
<td>0.0163</td>
<td>0.0263</td>
<td>0.0237</td>
<td>0.0163</td>
<td>0.3427</td>
<td>0.0295</td>
<td>0.0121</td>
</tr>
<tr>
<td>PRS.IND.1SG</td>
<td>0.6990</td>
<td>0</td>
<td>0.6366</td>
<td>0.6990</td>
<td>0.6594</td>
<td>0.6832</td>
<td>0.6761</td>
<td>0.6990</td>
<td>0.6990</td>
<td>0.7855</td>
<td>0.6821</td>
<td>0.6678</td>
</tr>
<tr>
<td>PRS.IND.3SG</td>
<td>0.2044</td>
<td>0.0819</td>
<td>0</td>
<td>0.2044</td>
<td>0.0041</td>
<td>0.0856</td>
<td>0.0856</td>
<td>0.2042</td>
<td>0.2382</td>
<td>0.0848</td>
<td>0.1461</td>
<td>0.0837</td>
</tr>
<tr>
<td>PRS.IND.2PL</td>
<td>0.0316</td>
<td>0.3422</td>
<td>0.3574</td>
<td>0</td>
<td>0.3605</td>
<td>0.0316</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.3422</td>
<td>0.0307</td>
<td>0.0311</td>
</tr>
<tr>
<td>PRS.IND.3PL</td>
<td>0.2124</td>
<td>0.1012</td>
<td>0.0059</td>
<td>0.2124</td>
<td>0</td>
<td>0.0859</td>
<td>0.0856</td>
<td>0.2084</td>
<td>0.2102</td>
<td>0.0936</td>
<td>0.1469</td>
<td>0.0838</td>
</tr>
<tr>
<td>PST.IPFV.IND.3SG</td>
<td>0.2184</td>
<td>0.4136</td>
<td>0.3755</td>
<td>0.2300</td>
<td>0.3812</td>
<td>0</td>
<td>0</td>
<td>0.2120</td>
<td>0.2011</td>
<td>0.4136</td>
<td>0.0609</td>
<td>0.0094</td>
</tr>
<tr>
<td>PST.PFV.IND.1SG</td>
<td>0.2594</td>
<td>0.4102</td>
<td>0.3720</td>
<td>0.2525</td>
<td>0.3773</td>
<td>0.0471</td>
<td>0</td>
<td>0.2592</td>
<td>0.2464</td>
<td>0.4102</td>
<td>0.1062</td>
<td>0.0563</td>
</tr>
<tr>
<td>PST.PFV.IND.3SG</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.3498</td>
<td>0.0136</td>
<td>0.3521</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.0016</td>
<td>0.0030</td>
</tr>
<tr>
<td>FUT.IND.3SG</td>
<td>0.0333</td>
<td>0.3441</td>
<td>0.3776</td>
<td>0.0650</td>
<td>0.3699</td>
<td>0.0533</td>
<td>0.0245</td>
<td>0.0345</td>
<td>0</td>
<td>0.3441</td>
<td>0.0444</td>
<td>0.0203</td>
</tr>
<tr>
<td>PRS.SBJV.3SG</td>
<td>0.1894</td>
<td>0.0000</td>
<td>0.0657</td>
<td>0.1894</td>
<td>0.0632</td>
<td>0.1350</td>
<td>0.1350</td>
<td>0.1894</td>
<td>0.1894</td>
<td>0</td>
<td>0.0917</td>
<td>0.1332</td>
</tr>
<tr>
<td>PRS.SBJV.2PL</td>
<td>0.2049</td>
<td>0.3912</td>
<td>0.4138</td>
<td>0.2049</td>
<td>0.4187</td>
<td>0.0483</td>
<td>0.0483</td>
<td>0.2049</td>
<td>0.1836</td>
<td>0.3912</td>
<td>0.0483</td>
<td>0</td>
</tr>
<tr>
<td>PST.PTCP</td>
<td>0.2109</td>
<td>0.4218</td>
<td>0.3431</td>
<td>0.2133</td>
<td>0.3806</td>
<td>0.0191</td>
<td>0.191</td>
<td>0.2209</td>
<td>0.1970</td>
<td>0.4218</td>
<td>0.0657</td>
<td>0</td>
</tr>
</tbody>
</table>
Exceptions to vowel reduction

- While vowel reduction in unstressed position is the default behavior, it is not systematic.
- This causes more uncertainty now in the opposite direction: when predicting a cell with an unstressed prethematic vowel from a cell with a stressed prethematic vowel, uncertain whether reduction will take place.

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>achar</td>
<td>eʃəɾ</td>
<td>aʃu</td>
<td>əʃəʃ</td>
<td>əʃə</td>
<td>eʃemus</td>
<td>eʃaiʃ</td>
<td>əʃẽũ</td>
</tr>
<tr>
<td>relaxar</td>
<td>rələʃəɾ</td>
<td>rələʃu</td>
<td>rələʃəʃ</td>
<td>rələʃə</td>
<td>rələʃemus</td>
<td>rələʃaiʃ</td>
<td>rələʃẽũ</td>
</tr>
<tr>
<td>vetar</td>
<td>vətəɾ</td>
<td>vətəu</td>
<td>vətəʃ</td>
<td>vətə</td>
<td>vətəməʃ</td>
<td>vətəaiʃ</td>
<td>vətəẽũ</td>
</tr>
<tr>
<td>encetar</td>
<td>ĕsətəɾ</td>
<td>ĕsətəu</td>
<td>ĕsətəʃ</td>
<td>ĕsətə</td>
<td>ĕsətəməʃ</td>
<td>ĕsətəaiʃ</td>
<td>ĕsətəẽũ</td>
</tr>
</tbody>
</table>
Causes of low predictiveness

Prethematic vowels

Exceptions to vowel reduction

- The effects of exceptions to vowel reduction are subtle.

- However in a few cases they are the main cause of uncertainty.

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>PRS.IND.1SG</th>
<th>PRS.IND.3SG</th>
<th>PRS.IND.2PL</th>
<th>PRS.IND.3PL</th>
<th>PST.IPV.IND.3SG</th>
<th>PST.IPV.IND.1SG</th>
<th>PST.IPV.IND.3SG</th>
<th>PST.SBJV.3SG</th>
<th>PST.SBJV.2PL</th>
<th>PST.PTCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>INF</td>
<td>0</td>
<td>0.3427</td>
<td>0.3032</td>
<td>0.0541</td>
<td>0.3706</td>
<td>0.0163</td>
<td>0.0163</td>
<td>0.0263</td>
<td>0.3427</td>
<td>0.0295</td>
<td>0.0121</td>
</tr>
<tr>
<td>PRS.IND.1SG</td>
<td>0.6990</td>
<td>0</td>
<td>0.6366</td>
<td>0.6990</td>
<td>0.6594</td>
<td>0.6832</td>
<td>0.6761</td>
<td>0.6990</td>
<td>0.7855</td>
<td>0.6821</td>
<td>0.6678</td>
</tr>
<tr>
<td>PRS.IND.3SG</td>
<td>0.2044</td>
<td>0.0819</td>
<td>0</td>
<td>0.2044</td>
<td>0.0041</td>
<td>0.0856</td>
<td>0.0856</td>
<td>0.2042</td>
<td>0.2382</td>
<td>0.0848</td>
<td>0.1461</td>
</tr>
<tr>
<td>PRS.IND.2PL</td>
<td>0.0316</td>
<td>0.3422</td>
<td>0.3574</td>
<td>0</td>
<td>0.3605</td>
<td>0.0316</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.3422</td>
<td>0.0307</td>
<td>0.0311</td>
</tr>
<tr>
<td>PRS.IND.3PL</td>
<td>0.2124</td>
<td>0.1012</td>
<td>0.0059</td>
<td>0.2124</td>
<td>0</td>
<td>0.0859</td>
<td>0.0856</td>
<td>0.2084</td>
<td>0.2102</td>
<td>0.0936</td>
<td>0.1469</td>
</tr>
<tr>
<td>PST.IPV.IND.3SG</td>
<td>0.2184</td>
<td>0.4136</td>
<td>0.3755</td>
<td>0.2300</td>
<td>0.3812</td>
<td>0</td>
<td>0</td>
<td>0.2120</td>
<td>0.2011</td>
<td>0.4136</td>
<td>0.0609</td>
</tr>
<tr>
<td>PST.IPV.IND.1SG</td>
<td>0.2594</td>
<td>0.4102</td>
<td>0.3720</td>
<td>0.2525</td>
<td>0.3773</td>
<td>0.0471</td>
<td>0</td>
<td>0.2592</td>
<td>0.2464</td>
<td>0.4102</td>
<td>0.1062</td>
</tr>
<tr>
<td>PST.IPV.IND.3SG</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.3498</td>
<td>0.0136</td>
<td>0.3521</td>
<td>0</td>
<td>0</td>
<td>0.0030</td>
<td>0.3316</td>
<td>0.0016</td>
<td>0.0030</td>
</tr>
<tr>
<td>FUT.IND.3SG</td>
<td>0.0333</td>
<td>0.3441</td>
<td>0.3776</td>
<td>0.0650</td>
<td>0.3699</td>
<td>0.0533</td>
<td>0.0245</td>
<td>0.0345</td>
<td>0</td>
<td>0.3441</td>
<td>0.0444</td>
</tr>
<tr>
<td>PRS.SBJV.3SG</td>
<td>0.1894</td>
<td>0.0000</td>
<td>0.0657</td>
<td>0.1894</td>
<td>0.0632</td>
<td>0.1350</td>
<td>0.1350</td>
<td>0.1894</td>
<td>0</td>
<td>0.0917</td>
<td>0.1332</td>
</tr>
<tr>
<td>PRS.SBJV.2PL</td>
<td>0.2049</td>
<td>0.3912</td>
<td>0.4138</td>
<td>0.2049</td>
<td>0.4187</td>
<td>0.0483</td>
<td>0.0483</td>
<td>0.2049</td>
<td>0.1836</td>
<td>0.3912</td>
<td>0.0483</td>
</tr>
<tr>
<td>PST.PTCP</td>
<td>0.2109</td>
<td>0.4218</td>
<td>0.3431</td>
<td>0.2133</td>
<td>0.3806</td>
<td>0.0191</td>
<td>0.0191</td>
<td>0.2209</td>
<td>0.1970</td>
<td>0.4218</td>
<td>0.0657</td>
</tr>
</tbody>
</table>
### Other causes of low predictiveness

<table>
<thead>
<tr>
<th>Irregular endings</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEDER</td>
<td>sˈedu</td>
<td>sˈedə</td>
<td>sˈedə</td>
<td>sədˈemus</td>
<td>sədˈəif</td>
<td>sˈedəɛ̃ĩ</td>
<td>99</td>
</tr>
<tr>
<td>QUERER</td>
<td>kˈɛru</td>
<td>kˈɛrəf</td>
<td>kˈɛr</td>
<td>kərˈemus</td>
<td>kərˈəif</td>
<td>kˈɛrəɛ̃ĩ</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stem allomorphy</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>RANGER</td>
<td>rˈɛzu</td>
<td>rˈɛzəf</td>
<td>rˈɛzəf</td>
<td>rɛzˈemus</td>
<td>rɛzˈəif</td>
<td>rˈɛzəɛĩ</td>
<td>196</td>
</tr>
<tr>
<td>MANTER</td>
<td>mɛtˈɛn ]</td>
<td>mɛtˈɛif</td>
<td>mɛtˈɛi</td>
<td>mɛtˈemus</td>
<td>mɛtˈɛdəf</td>
<td>mɛtˈɛɛĩ</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suppletion</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND.PRS</td>
<td>sˈo</td>
<td>ˈɛʃ</td>
<td>ˈɛ</td>
<td>sˈomus</td>
<td>sˈoiʃ</td>
<td>sˈɛu</td>
</tr>
<tr>
<td>IND.PST.IPV</td>
<td>ɛra</td>
<td>ɛraʃ</td>
<td>ɛra</td>
<td>ɛremus</td>
<td>ɛreʃ</td>
<td>ɛreũ</td>
</tr>
<tr>
<td>IND.PST.PFV</td>
<td>fui</td>
<td>ʃoʃtə</td>
<td>foi</td>
<td>fomus</td>
<td>ʃoʃtəf</td>
<td>fɔɾẽũ</td>
</tr>
</tbody>
</table>

*However the prevalence of these phenomena in Portuguese is low and hence makes only a small contribution to uncertainty.*
Joint predictiveness

- Joint predictiveness: prediction from knowledge of two or more cells
  - Stump and Finkel (2013) on principal part systems

- The interplay between vowel alternations and theme vowel reductions entails that no single cell can be a good predictor of the whole paradigm.
  - No cell with stress on the prethematic vowel makes a three way distinction of theme vowels.
  - Many pairs combining
    - a cell with a three-way distinction in endings
    - a cell with pre-thematic stress
  are perfect overall predictors of the paradigm (i.e., constitute a set of principal parts).

- Some other pairs of cells have surprisingly good joint predictiveness.
- A case in point: PRS.1SG and PRS.3SG
Joint predictiveness

- 2nd and 3rd conjugation verbs have raised prethematic mid-vowels in the PRS.1SG

<table>
<thead>
<tr>
<th></th>
<th>INF</th>
<th>1SG</th>
<th>2SG</th>
<th>3SG</th>
<th>1PL</th>
<th>2PL</th>
<th>3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVAR</td>
<td>lev'ar</td>
<td>l'evu</td>
<td>l'evas</td>
<td>l'eva</td>
<td>lev'emus</td>
<td>lev'aiS</td>
<td>l'evēn</td>
</tr>
<tr>
<td>NOTAR</td>
<td>nut'ar</td>
<td>n'otu</td>
<td>n'otas</td>
<td>n'ete</td>
<td>nut'emus</td>
<td>nut'aiS</td>
<td>n'otēn</td>
</tr>
<tr>
<td>RECEBER</td>
<td>rəsəb'er</td>
<td>rəsəbu</td>
<td>rəsəbes</td>
<td>rəsəe</td>
<td>rəsəb'emus</td>
<td>rəsəb'aiS</td>
<td>rəsəbēn</td>
</tr>
<tr>
<td>RECORRER</td>
<td>rəkər'er</td>
<td>rəkəru</td>
<td>rəkəres</td>
<td>rəkəe</td>
<td>rəkər'emus</td>
<td>rəkər'aiS</td>
<td>rəkərēn</td>
</tr>
<tr>
<td>SEGUIR</td>
<td>seg'ir</td>
<td>sigu</td>
<td>s'egəʃ</td>
<td>s'egə</td>
<td>seg'imus</td>
<td>seg'aiS</td>
<td>s'egēn</td>
</tr>
<tr>
<td>SUBIR</td>
<td>sub'ir</td>
<td>subu</td>
<td>s'obəʃ</td>
<td>s'obə</td>
<td>sub'imus</td>
<td>sub'aiS</td>
<td>s'obēn</td>
</tr>
</tbody>
</table>

- As a result, the PRS.1SG sometimes disambiguates between 2nd and 3rd conjugation

\[
\langle \text{PRS.1SG,PRS.3SG} \rangle \rightarrow \text{INF}
\]

\[
\langle \text{XiCu, XəCə} \rangle \rightarrow \text{XəCir}
\]

\[
\langle \text{XeCu, XəCə} \rangle \rightarrow \text{XəCer}
\]
Conclusions

We have illustrated the use of IPa methods for the practical description of inflection systems

- Inflectional classification (clustering of lexemes)
- Paradigm partition (clustering of cells)
- Cell predictiveness
  - Elaboration of (Ackerman et al., 2009) etc.

Striking result: in Portuguese conjugation, most complexity results from historically motivated but now morphologized patterns of vowel alternation.

Thus patterns orthogonal to exponence are crucial to an understanding of the system.

While there are ways of accounting for such patterns (e.g. morphomic stem alternants, morphophonological rules), one virtue of the current method is to help us find the patterns and evaluate their relevance.
References I


References II


