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G2P-DLP: An Open-Source System for Grapheme-to-Phoneme Conversion

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3rd International Conference on Data & Digital Humanities
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ELACH, University of Minho, Portugal

Agenda

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1. Introduction

European Portuguese currently lacks openly accessible grapheme-to-phoneme (G2P) tools, **limiting access to phonological data** and thus **hindering phonological research and education**

This work **addresses this gap** by introducing a G2P system:

Findable
Accessible
Interoperable
Reusable

2. G2P Systems

Traditionally, **G2P (grapheme-to-phoneme) systems** convert written text into phonetic representations.
But also…

- syllabic divider
- stress marker
- phonetic transcriber

Efforts to develop these systems for **European Portuguese** have produced a range of algorithms and models based on…

- **linguistic rules** (Oliveira *et al.*, 1992; Caseiro *et al.*, 2002; Teixeira, 2004; Braga *et al*, 2006)
- **statistical data** (Trancoso *et al.*, 1994; Oliveira *et al.*, 2001; Barros & Weiss, 2006)
- **hybrid combination** (Candeias & Perdigão, 2011)

2. G2P Systems

Grafone

https://portulanclarin.net/workbench/it-grafone/

absence of information about the phonetic conventions and characters (*e.g.*, representation of the central vowel [ɨ] as /ə/)

incorrections in the transcription of certain vowels (*e.g.*, bebé, */bəbˈɛ/)

Convert Text to IPA Transcription

https://european-portuguese.info/ipa#Ol%C3%A1%20mundo!

inconsistencies on the transcription of certain vowels (*e.g.*, amarelo *[ɐ.mɐ.ˈɾ**e**.lu]) and the diphthong [ɔj] (*e.g.*, comboio *[kõ.ˈboj.u])

incorrections in the transcription of certain vowels (*e.g.*, normal *[n**u**ɾ.ˈmaɬ])

They are NOT reproducible or transparent, as their underlying methodologies and datasets remain undisclosed to the public

3. Methodology Overview

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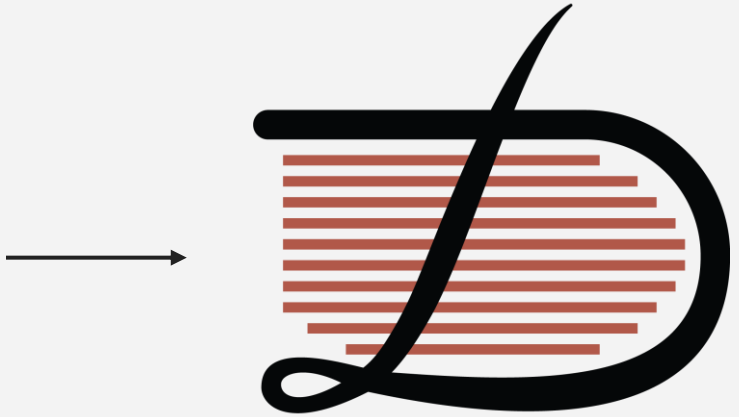
3.1. Data

To develop and evaluate our system, we adopted a **dictionary-based approach**, which relies on a list of words (a **lexicon**) corresponding to the **lemmas** of the *Dicionário da Língua Portuguesa* of the Academy of Sciences of Lisbon (DLP-ACL)

	A	B	C	D
1	aberto			
2	alegre			
3	anterior			
4	atento			
5	barato			
6	básico			
7	brilhante			
8	central			
9	certo			
10	clássico			
11	colorido			
12	completo			



https://dicionario.acad-ciencias.pt/

3. Methodology Overview

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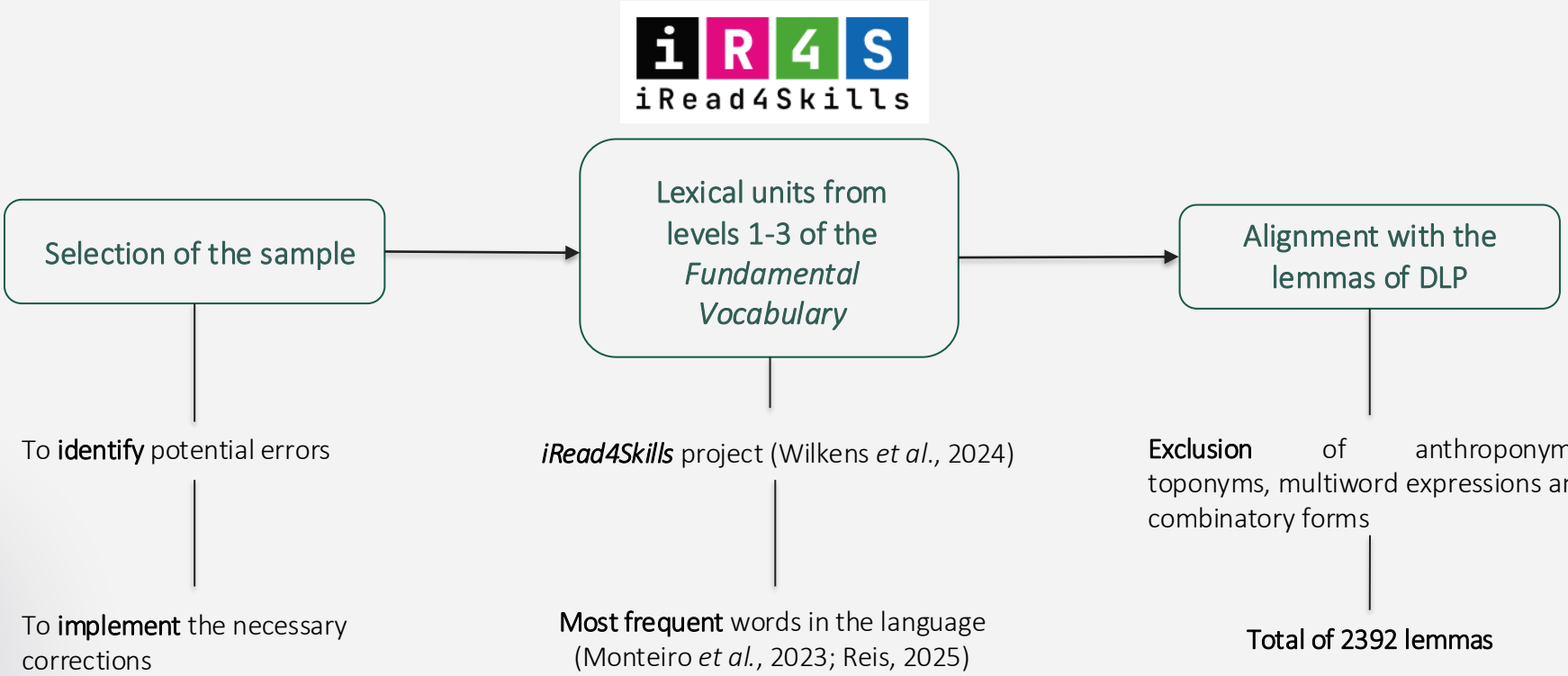
3.1. Data



3.2. Regular Expressions

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Regular expressions (**regex**) are versatile search patterns, effective in identifying and/or modifying data based on predefined character sequences (Goyvaerts, 2007; Goyvaerts & Levithan, 2009)

- broad applicability
- high interoperability
- great stability across software environments

Sample of the syntax of regex characters

Character	Description	Example
^	Selects the initial position	^g → **g**anhar
$	Selects the final position	á$ → c**á**
(|)	Selects the character(s) on the left OR the character(s) on the right	(m|n|lh) → **m**a**lh**a; **m**a**n**a; **m**ala
(?=) (*positive lookahead*)	Selects the character when it is followed by what goes after =	p(?=ão) → p**ão**; p**ã**
(?!) (*negative lookahead*)	Selects the character when it is NOT followed by what goes after !	p(?!e) → perto; **p**reto; **p**orta
(?<=) (*positive lookbehind*)	Selects the character when it is preceded by what goes after =	(?<=o)l → v**o**ltar; possível
(?<!) (*negative lookbehind*)	Selects the character when it is NOT preceded by what goes after !	(?<!g)ui → seguir; aq**ui**lo

3.2. Pipeline architecture

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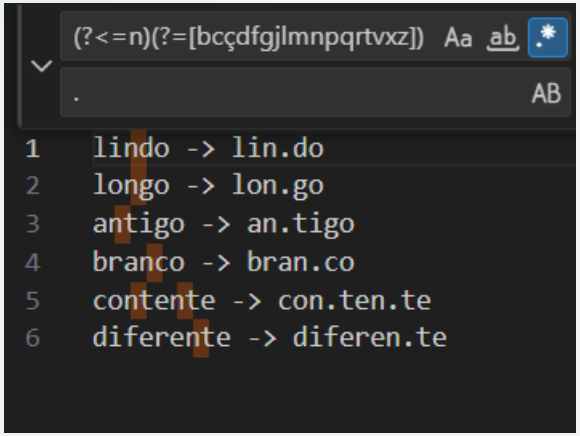

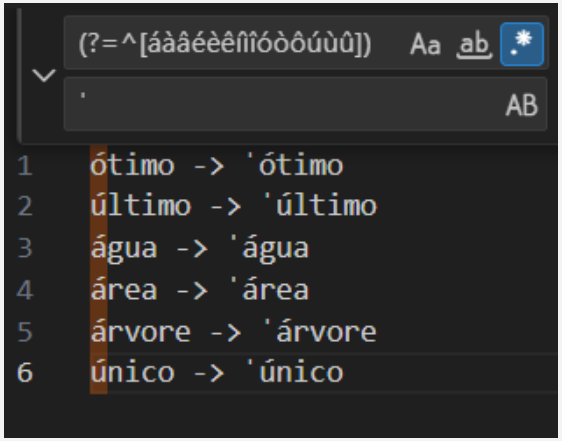

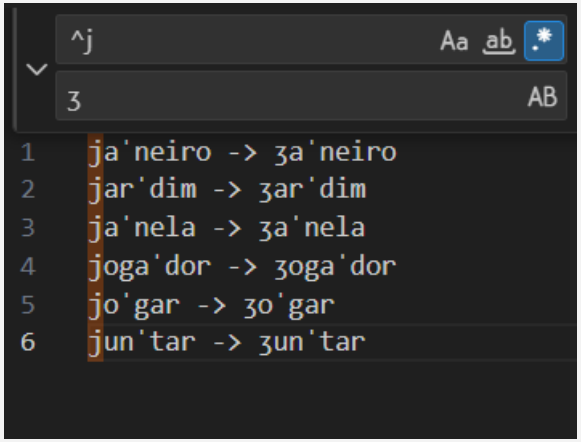

Syllabic Division

- selects a **boundary** between syllables
- inserts a **syllabic divider**

Stress Marking

- selects a **position** before a syllable or a **boundary** between syllables
- inserts a **stress marker**

Phonetic Transcription

- **replaces** a segment with another segment

3.2. Pipeline architecture

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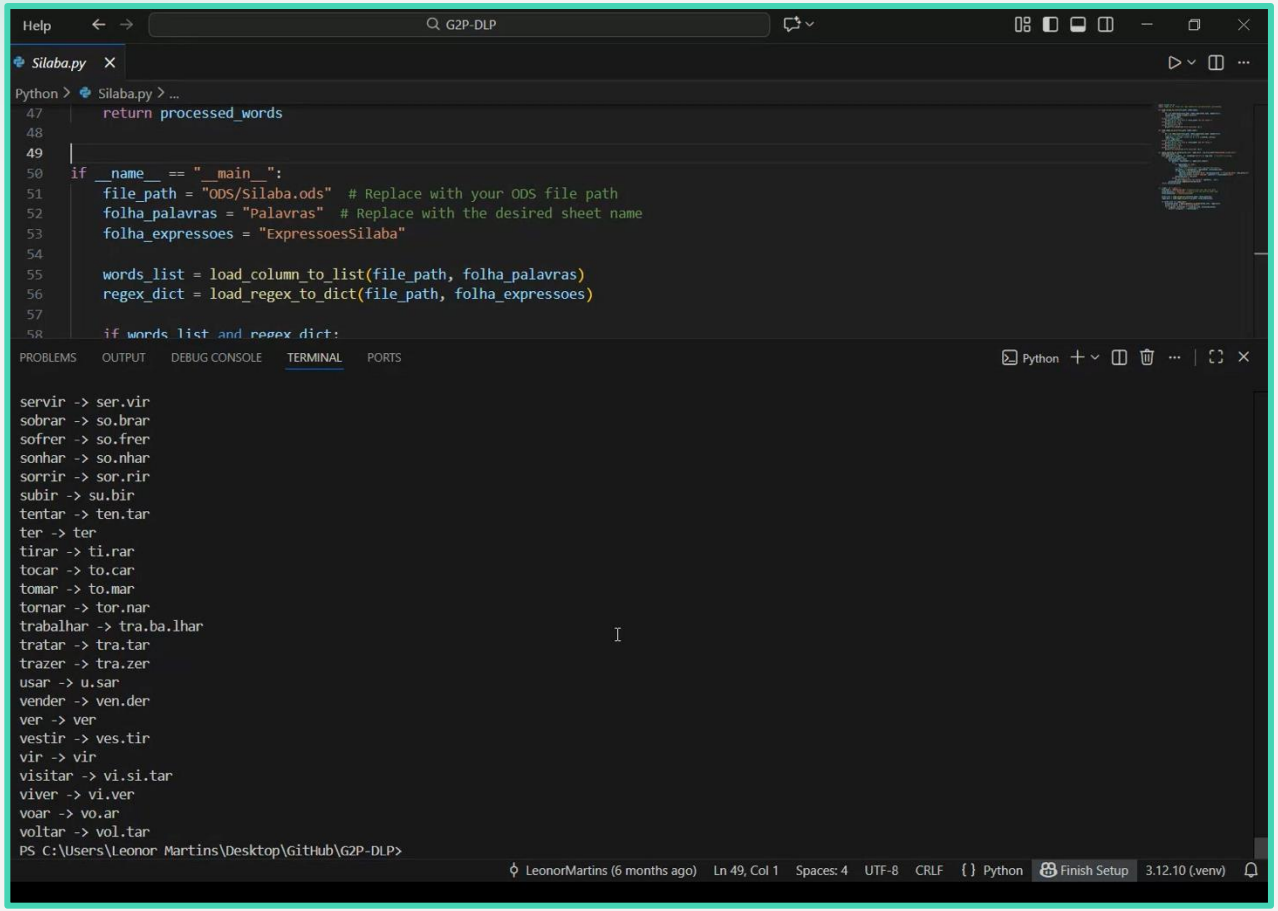


```
servir -> ser.vir
sobrar -> so.brar
sofrer -> so.frer
sonhar -> so.nhar
sorrir -> sor.rir
subir -> su.bir
tentar -> ten.tar
ter -> ter
tirar -> ti.rar
tocar -> to.car
tomar -> to.mar
tornar -> tor.nar
trabalhar -> tra.ba.lhar
tratar -> tra.tar
trazer -> tra.zer
usar -> u.sar
vender -> ven.der
ver -> ver
vestir -> ves.tir
vir -> vir
visitar -> vi.si.tar
viver -> vi.ver
voar -> vo.ar
voltar -> vol.tar
```

3.2. Pipeline architecture

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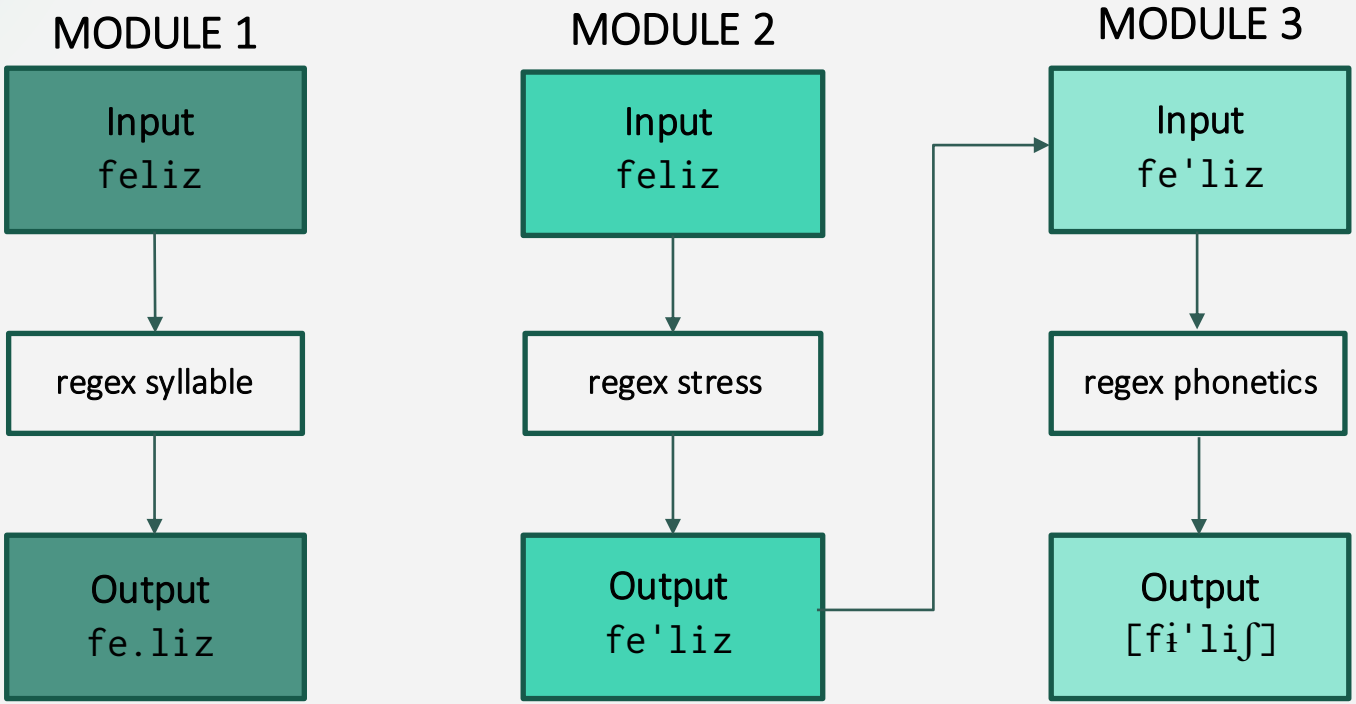

3.4. Open-Source Implementation

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Advanced regular expression processing

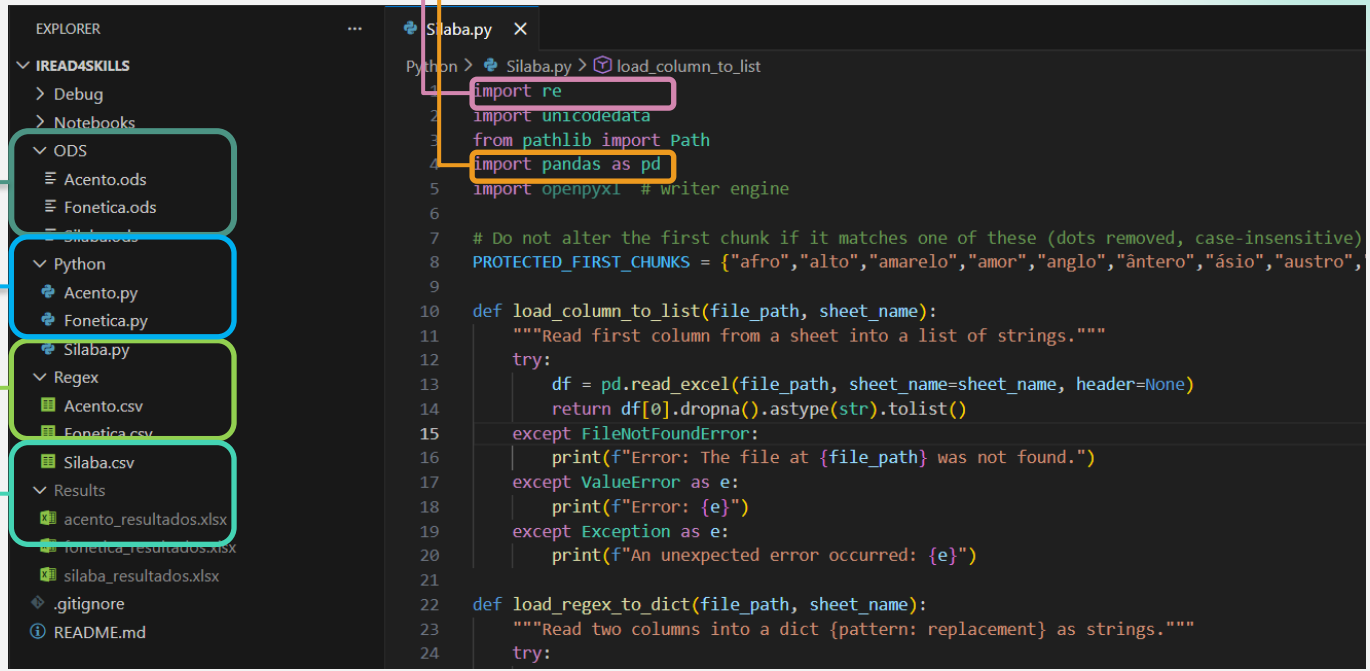
Reading and manipulating data in the ODS files

ODS
(input + regex)

Python
(script)

Regex
(ID, Examples)

Results
(ouput)



3.4. Open-Source Implementation

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GitHub

Repository Structure

```
├── Debug/
│   └── Log and debug files generated during the execution of the scripts and notebooks.
│
├── Notebooks/
│   └── Jupyter notebooks corresponding to the three modules (syllable, stress, phonetics).
│       They present the process of developing the Python files and the results obtained.
│
├── Python/
│   └── Standalone Python scripts for the three main modules.
│       - silaba.py
│       - acento.py
│       - fonetica.py
│
├── ODS/
│   └── ODS-format data files containing the corpora used in the modules.
│       These files specify the contexts, patterns, and substitutions applied.
│
├── Regex/
│   └── CSV tables with the regular expressions used in each module.
│       Each line includes:
│       - Regex ID
│       - Context Pattern
│       - Regex expression (Find)
│       - Applied substitution (Replace)
│       - Example of application
```

4. Results and Discussion

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4.1. Level 1

Syllabic Division

100%

All syllable boundaries were detected:
– C.C (partir → par.tir)
– V.C (tratar → tra.tar)
– G.C (baixo → bai.xo)
– G.V (meia → mei.a)
– V.V (voar → vo.ar)

Stress Marking

99.6%

All stress patterns were detected:
– **proparoxytones** (férias → **'fé**rias)
– **paroxytones** (festa → **'fes**ta)
– **oxytones** (flor → **'flor**)
Except *simples*, *apenas* and *menos*:
– *simˈples → ˈ simples
– *apeˈnas → a ˈ penas
– *meˈnos → ˈmenos

Phonetic Transcription

97.6%

All consonantal segments were correctly transcribed ([puˈxar] → [puˈʃar]).
The vowel segments were more problematic:
– *bebé*: *[bɨˈbɛ] → [bɛˈbɛ]
– *normal*: *[nurˈmaɬ] → [nɔrˈmaɬ]
– *ação*: *[ɐˈsɐ̃w̃] → [aˈsɐ̃w̃]
– *amanhã*: *[ɐmɐˈɲɐ̃] → [amɐˈɲɐ̃]

4.2. Levels 2 and 3: Scalability and Sustainability

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Syllabic Division

99.6%

A small set of **ambiguous graphemic sequences** challenged syllabification, namely **<ai>** and **<ui>**:
- rainha (r**a.i**.nha) *vs*. baixo (b**ai**.xo)
- fluidez (fl**u.i**.dez) *vs.* cuidar (c**ui**.dar)

Stress Marking

99.5%

The few deviations were limited to **predictable sources of ambiguity**:
- ambiguous graphemic sequences (*ˈjuiz → juˈiz)
- double marked words (*ˈórˈfão → ˈórfão)
- exceptions (*amˈbos → ˈambos)

Phonetic Transcription

97.7%

Errors were restricted to a small number of **well-defined contexts**:
- grapheme <x> (*exame*: *[eˈʃamɨ] → [eˈzamɨ])
- adverbs in *–mente* (*somente*: *[sᴜˈmẽtɨ] → [sɔˈmẽtɨ])
- exceptions of vowel reduction (coleção: *[kulɨˈsẽw̃] → [kulɛˈsẽw̃])

5. Future Applications and Implications

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Technical Framework and Sustainability

- uses **open-source**, **widely supported technologies**
- provides a **transparent**, **replicable**, and **extensible** framework
- flexibale architecture that supports **easy updates** and adaptation to **new corpora or languages**

Pedagogical Applications

- can be integrated into tools for **pronunciation training** and **language learning**
- supports **literacy development**, **first and second-language teaching** and the **creation of educational materials**

Educational Resource Development

- enables rapid production of **annotated datasets** that can be used in classroom resources
- supports teachers and learners through **standardized phonological representations**

Research and Linguistic Innovation

- facilitates **large-scale phonological analysis**
- could support **comparative studies on prosody** and serve as a preprocessing component for **speech technologies**
- contributes to **language conservation and revitalization**

6. Conclusion

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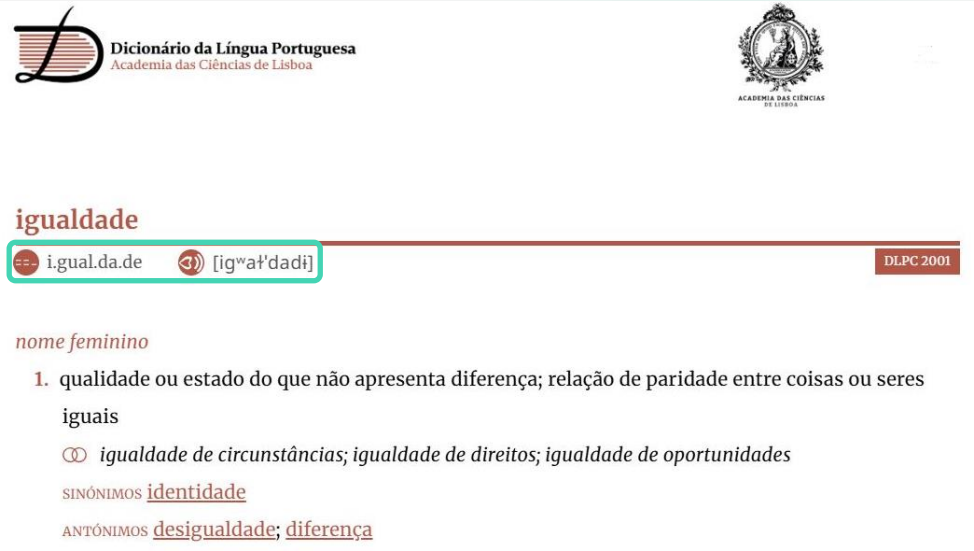
Our G2P system demonstrates **stability** and **accuracy** across various modules and dataset sizes

↓

Providing **openly available** solutions is crucial to enabling equitable and democratic participation in linguistic research and development

↓

This project offers a **FAIR resource** that illustrates the **impact of open infrastructutes**



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