

Rethinking Tools for the Morphosyntactic Analysis of Underdocumented Languages

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Collaboration with...



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 - Designed to increase **community engagement** with linguistic fieldwork.

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 - Fieldwork on underdocumented languages - challenges and stakeholders
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The plan

- The **problem**
 - Fieldwork on underdocumented languages - challenges and stakeholders
 - Morphosyntactic description and analysis
- The **solution**
 - The theory: Word-and-Paradigm morphology
 - The implementation: software and piloting
- What's **next**?

The problem

- **50-90%** of world's languages estimated to be **severely endangered or dead** by 2100 (Austin & Sallabank, 2011)

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- Communities shift to speaking majority languages
 - out of stigmatisation
 - as a means of seeking out opportunities

- Affected communities are losing part of their **identity**
- Humanity is losing access to **knowledge**
- Researchers are experiencing **artificially reduced variation** in the object of study

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- **Common tasks:**
 - Collect raw data (recordings of their community, writing up stories)
 - Data processing and analysis

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- Collecting raw data requires **mastering recording equipment/digitising notes**, which may already be a challenge
- The real **bottleneck** is involvement in **data processing and analysis**
 - **Technical barrier** to use existing software
 - Need for **linguistic training** for e.g. applying morphological labels

Documenting and analysing morphosyntactic structure

1. Eliciting basic vocabulary



squirrels



squids



cats

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2. Understanding the meaning of recurrent substrings

$XS = X.PLURAL$

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1. Eliciting basic **vocabulary**



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2. Understanding the **meaning of recurrent substrings**

$XS = X.PLURAL$

Morphosyntactic analysis is

- a crucial part of **describing** the linguistic system
- the basis for **glossing** – a way to convey linguistic structure for other purposes

Current standard morphosyntactic documentation practices

squirrel-s	would='ve	chase-d	mice
squirrel-PL	COND=PERF	chase-PST	PL\mouse

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Tricky for understudied languages

- **Theoretical issues**
 - Early commitment to an analysis
 - Assumption that all morphological patterns are easily described in concatenative terms

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- **Practical issues**

- Suboptimal use of human time
- Requires linguistic training

Existing software for annotation

- **Excel** is a popular choice - a dire situation

Microsoft Excel - test1k-Glong.xml.01.xls

	A	C	D	E	H	I	J	K	L	
1	n	beseda	lema	MSD	amb	Razvezano	Oz	levi kontekst	beseda	desni kontekst
2		<div>								
3		<p>								
4		<s>								
5	4	Slavko	Slavko	slmei	2/2	hoški	ednina	imenovnik		
6	5	Dragovan	Dragovan	pkomein	2	a	imenovnik	-določnost		
7	6	,								
8	7	župan	župan	Somei	1/2	hoški	ednina	imenovnik		
9	8	občine	občina	Sozer	3/5	ne ženski	ednina	rodnik		
10	9	Metlika	Metlika	Sizei	1/2	žanski	ednina	imenovnik		
11	10	:								
12	11	Se	še	L	1			Členek		
13	12	nikoli	nikoli	Rso	1/7	Pristav	splošni	osnovnik		
14	13	me	jaz	Zop-et---	3	nastavka	samostalniški			
15	14	ni	biti	IGvpat-e-d	1	lik	trejta	ednina	zanimani	občina Metlika : Se nikoli me ni bilo tako strah pod
16	15	bilo	biti	IGvdr-est-	2	lik	ednina	srednji	človek	ne Metlika : Se nikoli me ni bilo tako strah podpisat
17	16	tako	tako	Rso	3/7	Pristav	splošni	osnovnik		
18	17	strah	strah	Somei	2/2	hoški	ednina	imenovnik		
19	18	podpisati	podpisati	IGpn-----	1	enski	nedoločnik	dovršni	nikoli me ni bilo tako strah	podpisati
20	19	kakšne	kakšen	Zv-zer----	6/8	dnina	rodnik	pridevniki		kakšne pogodbe ku
21	20	pogodbe	pogodba	Sozer	3	ne ženski	ednina	rodnik		
22	21	kot	kot	Dpel	6/8	g	enostaven	imenovnik		
23	22	prav	práv	Rso	4	Pristav	splošni	osnovnik		
24	23	pogodbo	pogodba	Sozet	2	ne ženski	ednina	tožnik		
25	24	za	za	Dpet	2/3	redlog	enostaven	tožnik		
26	25	virtino	virtina	Sozet	2	ne ženski	ednina	tožnik		
27	26	.								
28	27	<s>								
29	28	Podpisuješ	podpisovati	IGpspde--n	1	ina	nezanikani	nedovršni		Podpisuješ nekaj, za kar dejaj
30	29	nekaj	nekaj	Zntset----	2/3	na	tožnik	samostalniški		
31	30	.								

1. Requires **non-trivial ease with technology**

- ...you are absolutely **overestimating the technological ability** of researchers, let alone of speakers.

Existing software for annotation - not so FLEx-ible

1. Requires **non-trivial technological ability**
2. Researchers often want to use the software in ways it was **not built for**
 - Multilingual/multimodal/multispeaker data

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 - Templatic morphology:

k-t-b katabtu aktubu kātibun

WRITE *I wrote* *I write* *he/she who writes*

All forms must be entered as "variants" - can't describe systematic relationships

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Often relies on **exporting and re-importing** to Python, ELAN, LaTeX, raising the technical barrier

Existing software for annotation - not so FLEx-ible

1. Requires **non-trivial technological ability**
2. Researchers often want to use the software in ways it was **not built for**
3. **Closed source proprietary software**: technically capable people can't implement or share improvements.
 - Particularly regrettable: hard to take advantage of **NLP and ML** technology built for aiding work on underdescribed languages.

The idea behind the solution

- **Word-and-Paradigm Morphology**
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 - Automatically **extending** the annotation and analysis to new data

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- Software that is **modular and open source**

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 - Describing a language's morphology amounts to making an **inventory of its FORM = MEANING pairings**.

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 - Describing a language's morphology amounts to making an **inventory of its FORM = MEANING pairings**.

-s = PLURAL; -ed = PAST; -er = AGENT

<i>workers</i> =	work-	+	-er	+	-s
		+	AGENT	+	PLURAL

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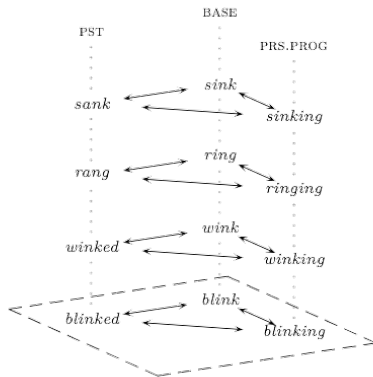
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 - The whole is often **more than the sum of its parts**:
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- **Word-based** approaches to morphology see the word as the **smallest unit of meaning**, rather than the morpheme, for the reasons above.

Doing morphology with word-based units

Define a word's meaning by the **place it occupies in the system**, relative to other words.



Morphology is about establishing **parallel analogical relationships between words**, and looking at the system as a whole.

Building up a picture of the system

Collect sets with **parallel relationships** of form and meaning

sink ~ sunk

ring ~ rung

*silk ~ *sulk

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These relationships can **span all the lexicon**

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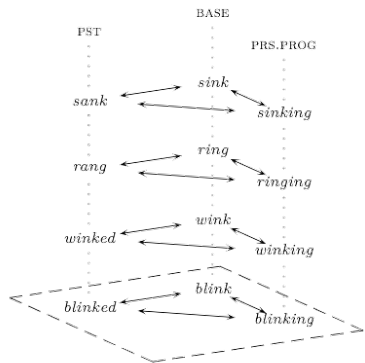
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ring ~ rung ~ ringable ~ ...

Morphological families are built up and aligned, starting from pairwise relationships

Word and Paradigm morphology

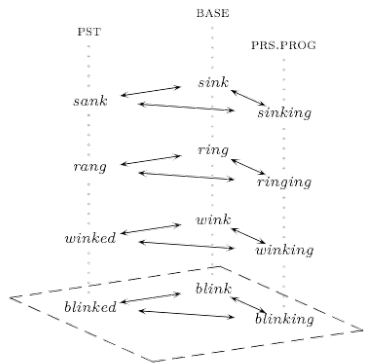
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Word and Paradigm morphology

- Establishing **parallel relationships of form and meaning** between words



- The **word is the smallest unit**
 - Defined by its place in a system of contrasts, not by its component parts
- Concepts like **paradigm cell** or **lexeme** are emergent
 - The result of establishing contrasts and similarities between words along different dimensions

The goal

Paradigmatic morphological analysis from documentary corpora

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 - Simple task: same or different?

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 - Simple task: same or different?
- **Active learning**
 - Updates the analysis after each annotator correction
 - Directs the annotator's attention to the most informative data points

The workflow

Step 1: Automated paradigm discovery

- Corpus of collected texts
 - + list of target lemmas
 - + unsupervised model (Jin et al. 2020)
 - = **initial unlabeled paradigms**

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 - + list of target lemmas
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- System searches a documentary corpus to identify related forms for each lexeme and **group surface forms into paradigms**

	Cell					
Lexeme	1	2	3	4	5	6
HEAR	hear	heard	-	hearing	heart	-
HELP	help	-	helped	helping	-	helps
			...			

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The Model:

Unsupervised Morphological Paradigm Completion (Jin et al., 2020)

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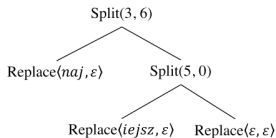


Figure 2: Visualization of the EDIT TREE constructed from *najtrudniejszy* to *trudny* (Chrupała, 2008).

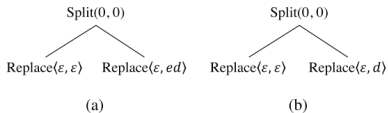


Figure 3: Visualization of the EDIT TREES representing (a) *work* \mapsto *worked* and (b) *continue* \mapsto *continued*.

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 - This is also often not the case!
e.g., English *read* can indicate 1SG.PRS, 1SG.PST, 2SG.PRS, 1PL.PRS...

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4. Assumes **concatenative** relationships and **consistent affix ordering**

Step 1: Automated paradigm discovery

The model's output:

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... it's a start! **Humans can help** :)

Step 2: Same or different? (Lexemes)

- Automatically extract examples of each **form in context** from the corpus
- The annotator marks **items that don't belong with the others**

File		
Lexicon Analogies Paradigms Texts		
Lexemes	Surface Forms	Concordances
DANCE	HEAR	? ...you're still going to hear them.
DRIVE	HEARS	? She thought she could hear Gomez laughing.
LIVE	HEARD	✗ ...signalling of problems of hearing and understanding.
HEAR	HEARING	✗ ...gray marble mausoleum at the heart of the city.
WORK	HEART	.
.	.	.
.	.	.
.	.	.
.	.	.

Step 3: Same or different? (Analogies)

- **Pairwise analogy** groups forms instantiating the same **paradigm cell**

The screenshot shows a software interface with a menu bar (File, Lexicon, Analogies, Paradigms, Texts) and a main workspace. The workspace is divided into three panels: 'Analogies', 'Concordances', and 'Xing'. The 'Analogies' panel lists pairs like 'X ~ Xment', 'X ~ Xer', 'X ~ Xing', 'X ~ Xed', and 'X ~ X'. The 'Concordances' panel is split into two columns: 'X' and 'Xing'. The 'X' column shows examples like 'We **publish** these ..', 'If we **learn** how...', and 'We **go** regularly to...', with green checkmarks and question marks indicating annotation status. The 'Xing' column shows examples like 'Time for **publishing** ..', 'Second language **learning** is ...', and 'She's not **going** to like ...'.

Analogies	Concordances	
	X	Xing
X ~ Xment		
X ~ Xer	✓ We publish these ..	Time for publishing ..
X ~ Xing	? If we learn how...	Second language learning is ...
X ~ Xed	? We go regularly to...	She's not going to like ...
X ~ X	.	.
.	.	.
.	.	.
.	.	.
.	.	.

- The annotator's task is the same: mark pairs that don't belong, and confirm those that do

The result: Unlabeled paradigms

File

LEXICON ANALOGIES PARADIGMS TEXTS

Lexemes

Search...

Show all words... ^

- look
- how
- focus
- involving
- it
- describes
- focusing
- focused
- works

Senses

View, edit and create word senses... v

Paradigm

Search...

looking	hearing	working		offering	playing
look	hear	work	describe	offer	play
looked		worked		offered	played
looks		works	describes	offers	plays

Experiments and results

- **Universal Dependencies** datasets for **English** and **Croatian** provide a gold standard for evaluation
- **Annotators**: 4 linguists (2 per language), fluent English speakers
 - English: **upper estimate** of model + annotator performance
 - Croatian: **unfamiliar language**
- 30 minutes per task: **lexeme groupings** + **cell groupings**

English & Croatian Results

Lexeme				Cell			
	Acc.	Marked	Corr.		Acc.	Marked	Corr.
English				English			
Base	81%	-	-	Base	67%	-	-
A1	84%	58	50	A1	97%	129	120
A2	83%	43	33	A2	94%	119	108
Croatian				Croatian			
Base	66%	-	-	Base	90%	-	-
A3	67%	19	19	A3	90%	8	-1
A4	66%	12	12	A4	90%	28	16

English & Croatian Results

Lexeme				Cell			
	Acc.	Marked	Corr.		Acc.	Marked	Corr.
English				English			
Base	81%	-	-	Base	67%	-	-
A1	84%	58	50	A1	97%	129	120
A2	83%	43	33	A2	94%	119	108
Croatian				Croatian			
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Case Study: Wao Terero

Wao Terero provides a demonstration of this workflow in the field.

- Linguistic isolate spoken in **Ecuadorian Amazon**
 - Estimated 1,200-3,000 speakers
 - No standard orthography
- **Collaboration** with native speakers (Spanish-Wao bilinguals)

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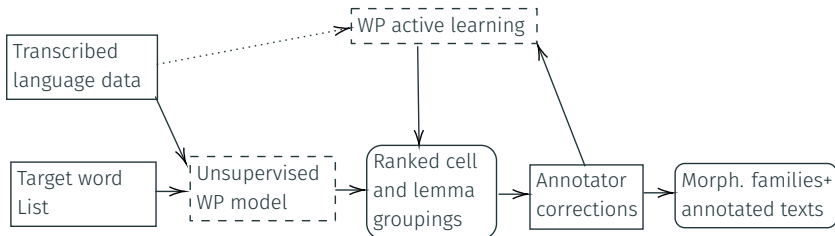
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 - annotate as many items (lexemes and paradigm cells) as possible within **1 hour**
- Annotators found the task **understandable** and **interesting**, with high inter-annotator agreement across annotated examples



Copot et al. (2022)
A Word-and-Paradigm Workflow for Fieldwork Annotation

In Development...

Implementing the Full Workflow



Ranking + Active Learning

- Warm start a supervised classifier using the unsupervised model's output as **silver data**
- System uses annotator's corrections for **active learning**

Lexemes	Surface Forms	Concordances
DANCE	HEAR	? ...you're still going to hear them.
DRIVE	HEARS	? She thought she could hear Gomez laughing.
LIVE	HEARD	X ...signalling of problems of hearing and understanding.
HEAR	HEARING	X ...gray marble mausoleum at the heart of the city.
WORK	HEART	.
.	.	.
.	.	.
.	.	.
.	.	.

- Items are reordered in real time for **efficient use of annotator time**

Ranking + Active Learning

- Analysis is pairwise-relational over sets of **formal**, **structural**, and **semantic** properties
- Lexeme and cell groupings **emerge** from the existence of shared relationships

The screenshot shows a software interface with a menu bar at the top containing 'File', 'Lexicon', 'Analogies', 'Paradigms', and 'Texts'. The 'Analogies' menu is currently selected, and the interface is divided into two main panels: 'Analogies' on the left and 'Concordances' on the right. The 'Concordances' panel is further divided into two sub-columns: 'X' and 'Xing'.

Analogies	X	Xing
X ~ Xment	✓ We publish these ..	Time for publishing ..
X ~ Xer	⊕ If we learn how...	Second language learning is ...
X ~ Xing	⊕ We go regularly to...	She's not going to like ...
X ~ Xed	.	.
X ~ X	.	.
.	.	.
.	.	.
.	.	.
.	.	.

Improving Unsupervised Paradigm Discovery

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- Want to incorporate derivational and agglutinative relationships to establish networks of **morphological families**
 - **Derivational:** *build ~ rebuild; build ~ builder; rebuild ~ rebuild*
 - **Agglutinative:** epäjärjestelmällistyttämättömyydellänsäkäänköhän
"I wonder if – even with his/her quality of not having been made unsystematized"

Conclusion

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Benefits of the Workflow for Linguistic Fieldwork

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- Defers difficult decisions about segmentation and labeling
 - Paradigmatic analysis of **morphological system as a whole**
- **Modular architecture:**
 - Future improvements in state of the art machine learning can immediately benefit annotator
- Annotation output may be used for **linguistic analysis** as well as **community resource development**

Many thanks to our consultants,
Flora and Alberto Boyotai!

Thank you!
