Unsupervised Decipherment of Informal Romanization

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Informal romanization

- *Romanization:* rendering non-Latin-script languages in Latin alphabet
- *Informal:* used online, arises out of Unicode/keyboard issues

Russian	*человек*	*chelovek, 4elovek, ceJIoBek, …*
Arabic	صباح	*saba7, sba7, sabah, …*
Greek	*ξένος*	*xenos, ksenos, 3enos, …*

Informal romanization

- Idiosyncratic representation: character subsititutions up to the user

Russian	*человек*	*chelovek, 4elovek, ceJloBek, …*
Arabic	صباح	*saba7, sba7, sabah, …*
Greek	*ξένος*	*xenos, ksenos, 3enos, …*

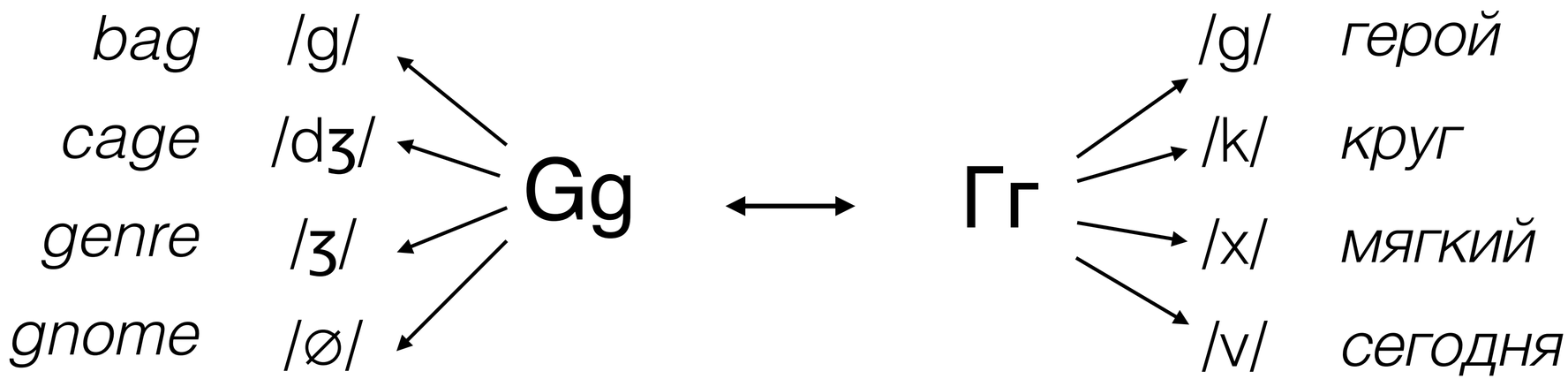
Informal romanization

- Idiosyncratic representation: character subsititutions up to the user
- Most substitutions are based on phonetic or visual similarity

Russian	*человек*	*chelovek, 4elovek, ceJloBek, …*
Arabic	صباح	*saba7, sba7, sabah, …*
Greek	*ξένος*	*xenos, ksenos, 3enos, …*

Phonetic romanization

- What does it mean for two characters to be phonetically similar?



- This is just in one language each!

Phonetic romanization

- What does it mean for two characters to be phonetically similar?
- Out-of-context grapheme-phoneme association: ɾ~/g/→g

Every letter makes a sound:
‘A’ says /eɪ/!*

*and /a/

https://www.youtube.com/watch?v=FFhH6576psw

Phonetic romanization

- What does it mean for two characters to be phonetically similar?
- Out-of-context grapheme-phoneme association: ɾ~/g/→g
- Phoneme produced in context: انتي /enti/→enty, صباح /sabaħ/→saba7

Visual romanization

- Broad similarity between glyph shapes
- Single characters can map to bi-/trigraphs
- Can be conditioned on a transformation
- Can be applied to a part of a glyph

а~/a/→a, г~/g/→r

ы→bl, ж→}|{

ɛ →3, л→v

ӈ →2

Character alignment

- Monotonic alignment that depends on the writing system of the language

Alphabet	Abjad (consonantal)	Abugida (alphasyllabary)
хорошо	كريم	ಬೆಳಗಿತು
		
xorosho	kareem	belagitu
~ one-to-one	~ one-to-one + null	~ one-to-many

Character alignment

- Monotonic alignment that depends on the writing system of the language

Alphabet

хорошо

xorosho

~ one-to-one

Abjad
(consonantal)

كريم

krym

kareem

~ one-to-one + null

Abugida
(alphasyllabary)

ಬೆಳಗಿತು

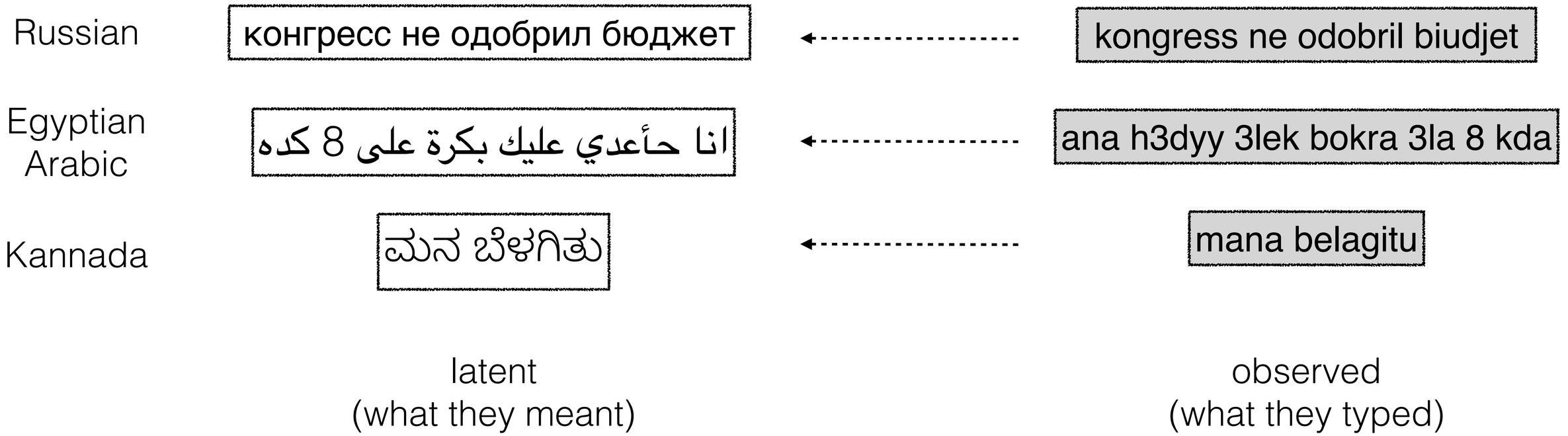
Unicode: ಬ ೆ ಳ ಗ ಿ ತ ು

belagitu

~ one-to-one + one-to-many

Task framing

- Convert romanized text to the conventional orthography of the language



Task framing

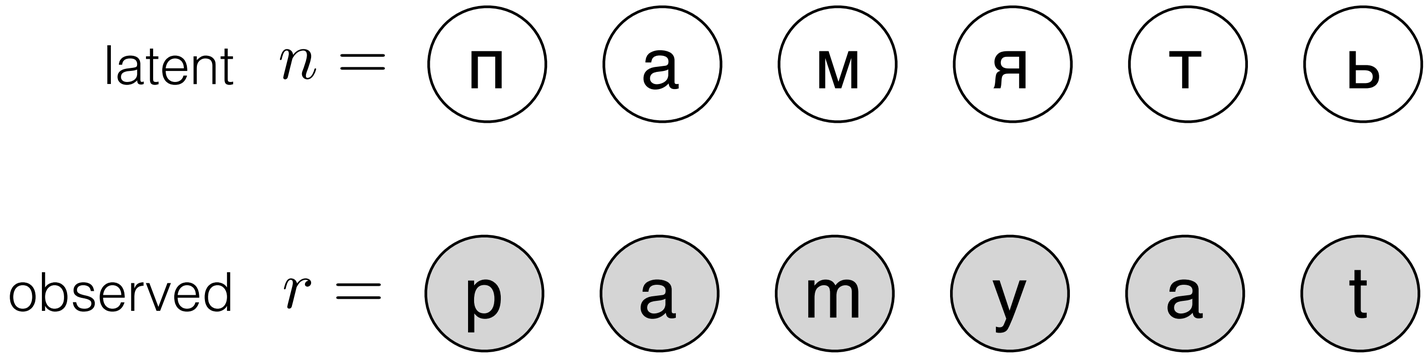
- Parallel data does not occur naturally ⇒ unsupervised learning
- Perceptions of similarity are shared across users and even languages!
- **Hypothesis**: inductive bias encoding these similarity notions provides signal that can somewhat approximate human supervision
  - We rely on manually-curated resources to operationalize it

M Ryskina, MR Gormley, T Berg-Kirkpatrick. Phonetic and Visual Priors for Decipherment of Informal Romanization. ACL 2020.

Decipherment

- Can be viewed as a decipherment task (Knight et al., 2006)

Noisy-channel model



$$p(r) = \sum_{n} p(n;\gamma) \cdot p(r|n;\theta) \cdot p_{\text{prior}}(\theta;\alpha)$$

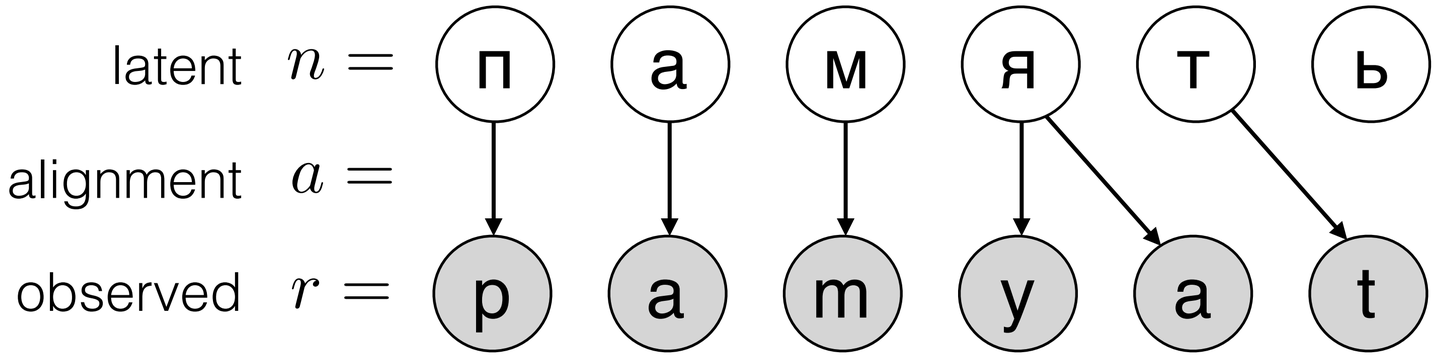
all possible native script sequences

transition probabilities

emission probabilities

prior on parameters

Noisy-channel model



$$p(r) = \sum_{n,a} p(n;\gamma) \cdot p(r|n,a;\theta) \cdot p_{\text{prior}}(\theta;\alpha)$$

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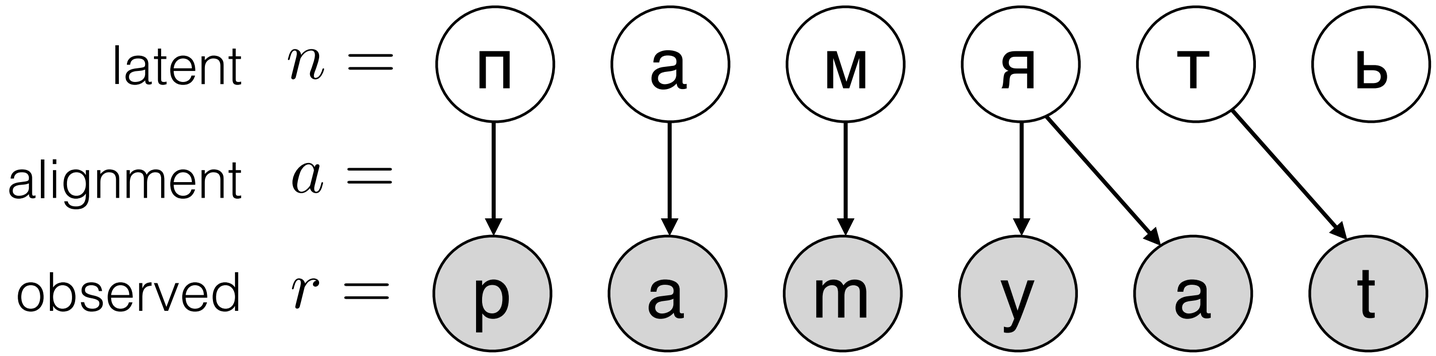

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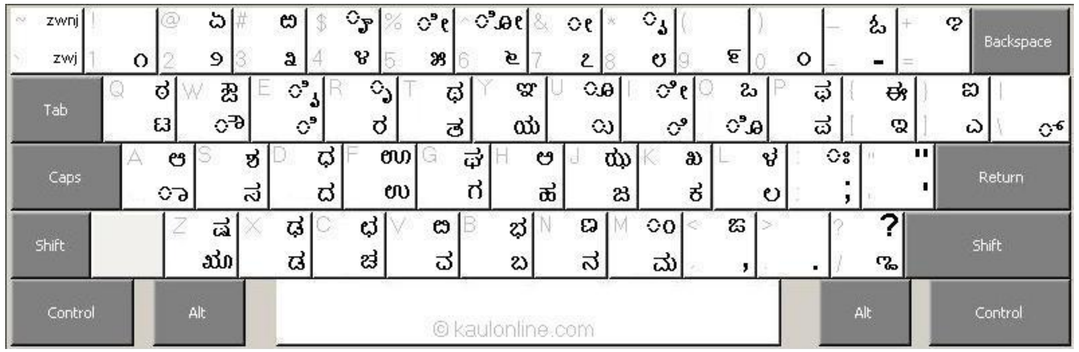
Phonetic bias

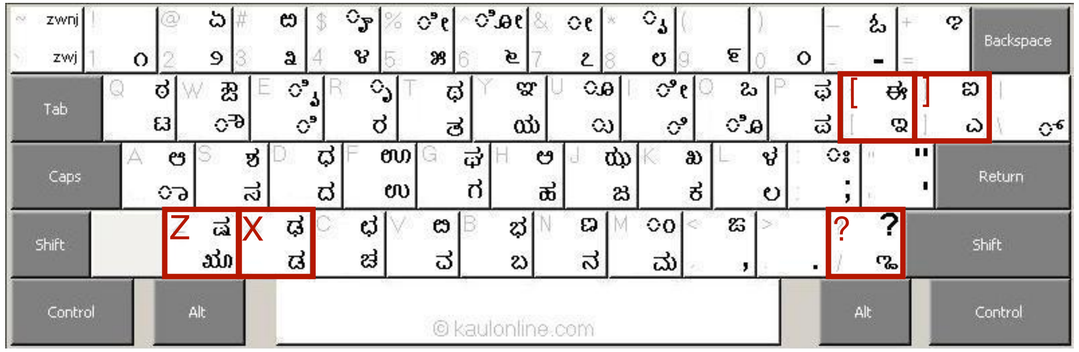
- Phonetic priors: mappings off phonetic keyboard layouts



https://en.wikipedia.org/wiki/Phonetic_keyboard_layout,
https://arabic.omaralzabir.com/, http://kaulonline.com/uninagari/kannada/

Phonetic bias

- Phonetic priors: mappings off phonetic keyboard layouts
  - One-to-one mapping constraints lead to spurious mappings



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Visual bias

- Visual priors: mappings off the Unicode confusables list

- Designed to combat spoofing attacks

y	ɣ	ʏ	γ	у	Ү	ყ
0079 LATIN SMALL LETTER Y	0263 LATIN SMALL LETTER GAMMA	028F LATIN LETTER SMALL CAPITAL Y	03B3 GREEK SMALL LETTER GAMMA	0443 CYRILLIC SMALL LETTER U	04AF CYRILLIC SMALL LETTER STRAIGHT U	10E7 GEORGIAN LETTER QAR
p	ρ	ϱ	р	⍴	⍴	𝐩
0070 LATIN SMALL LETTER P	03C1 GREEK SMALL LETTER RHO	03F1 GREEK RHO SYMBOL	0440 CYRILLIC SMALL LETTER ER	2374 APL FUNCTIONAL SYMBOL RHO	2CA3 COPTIC SMALL LETTER RO	1D429 MATHEMATICAL BOLD SMALL P

sigtyp.io

sigtyp.io

https://util.unicode.org/UnicodeJsps/confusables.jsp

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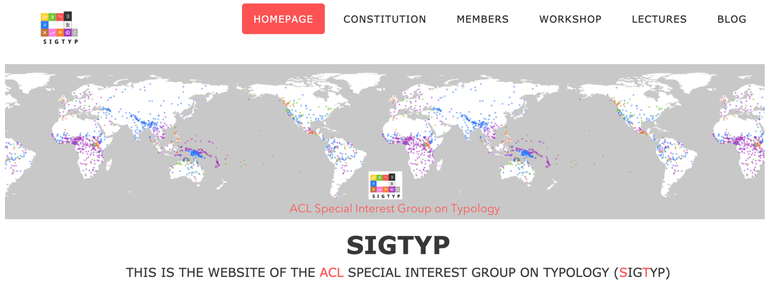

sigtyp.io

The site you just tried to visit looks fake. Attackers sometimes mimic sites by making small, hard-to-see changes to the URL.

https://util.unicode.org/UnicodeJsps/confusables.jsp

Visual bias

- Visual priors: mappings off the Unicode confusables list

- Designed to combat spoofing attacks

- Hardly any mappings for Arabic and Kannada!

ʏ	ɣ	ʏ	Ɣ	у	Ү	ყ
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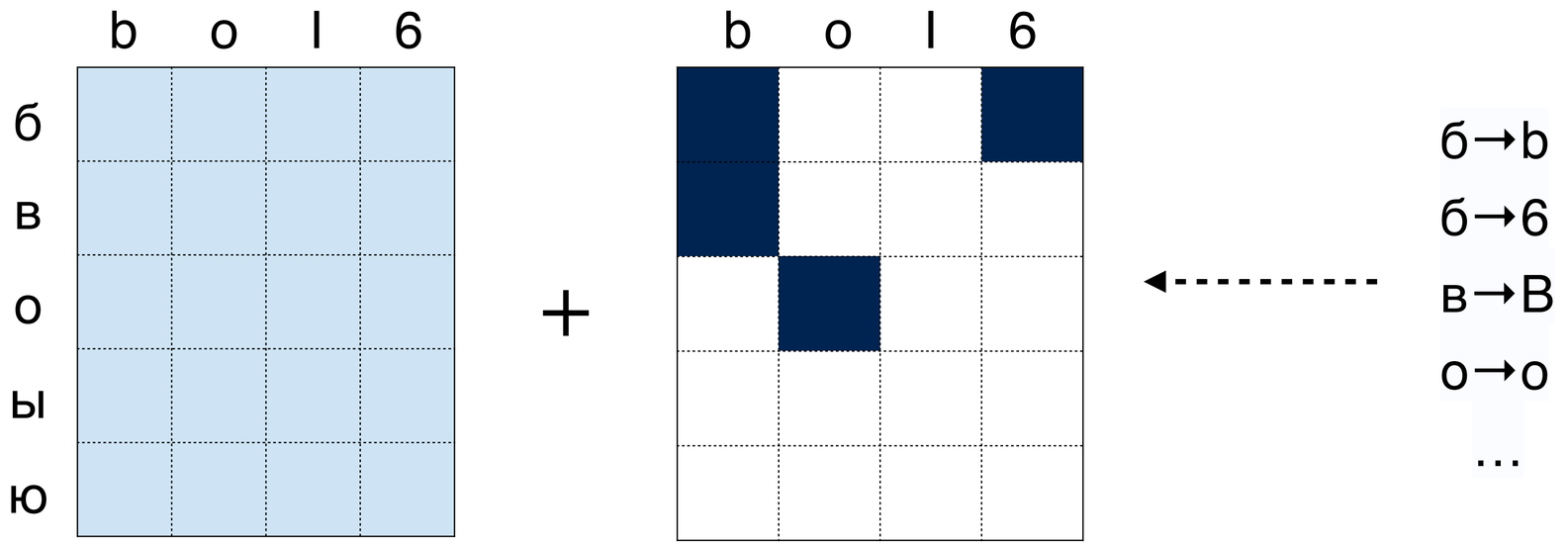
Informative priors

- Use mappings of similar characters as priors on emission parameters

$$c_r | c_n \sim \mathrm{Mult}(\theta_{c_n}) \qquad \theta \sim \mathrm{Dir}(\alpha)$$



Informative priors

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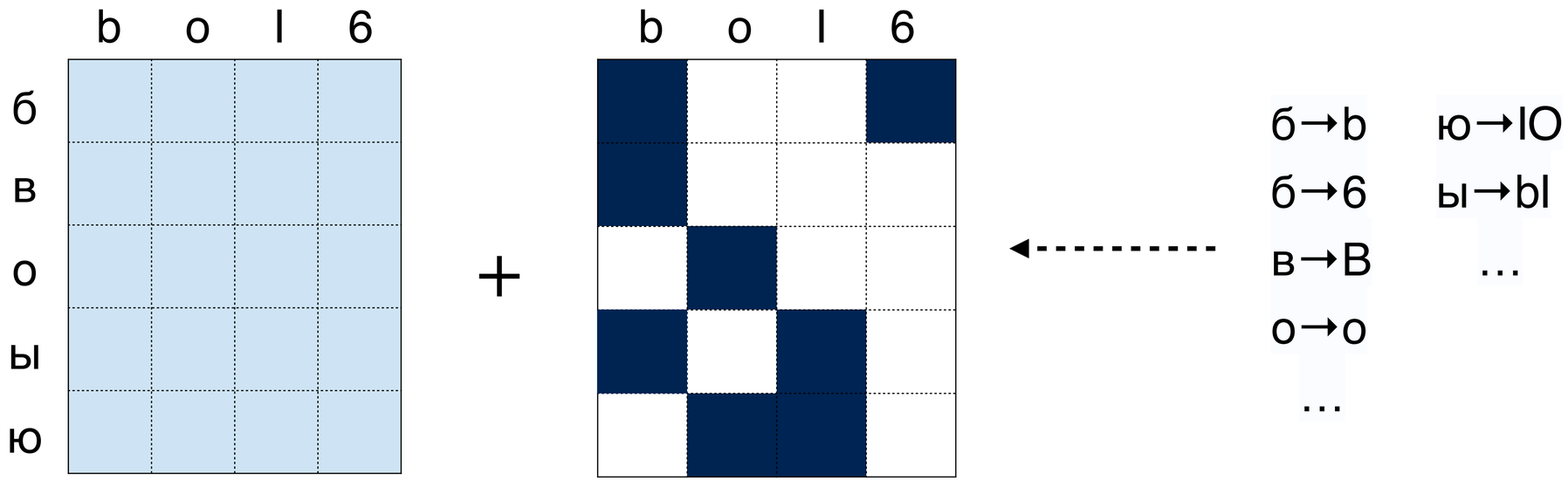
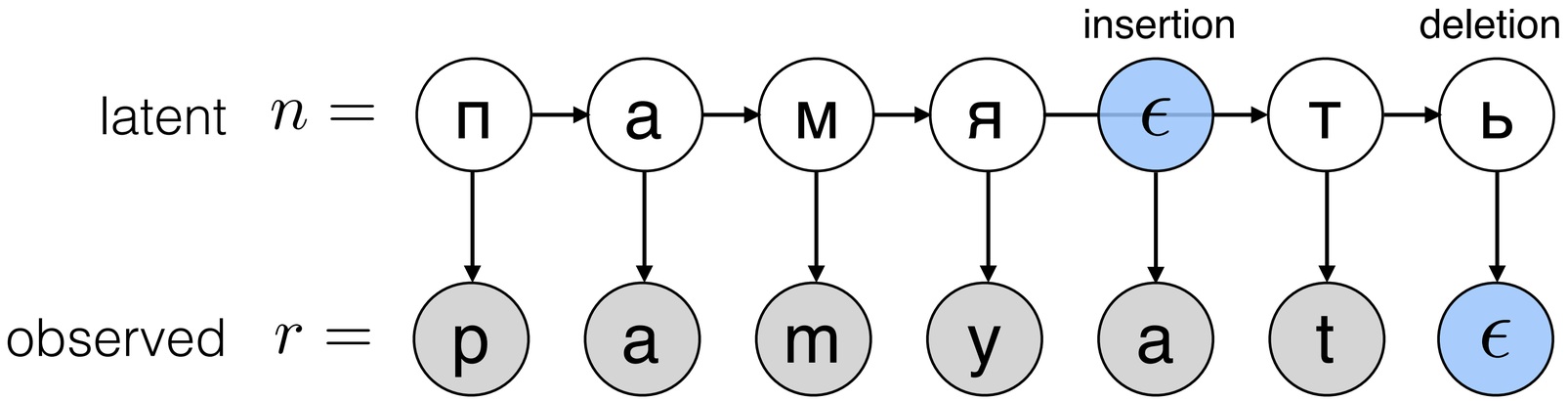


Noisy-channel model

- Representing latent alignments via insertions and deletions



$$p(r) = \sum_n p(n;\gamma) \cdot p(r|n;\theta) \cdot p_{\text{prior}}(\theta;\alpha)$$

transition probabilities

emission probabilities

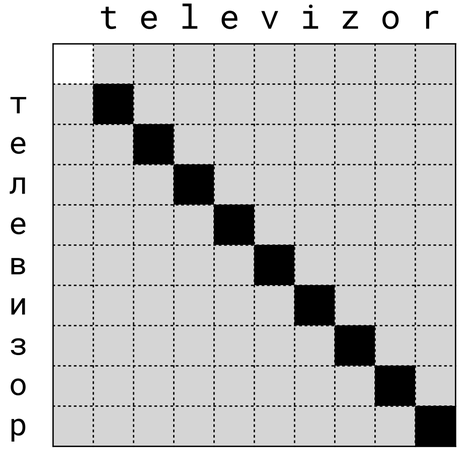
prior on parameters

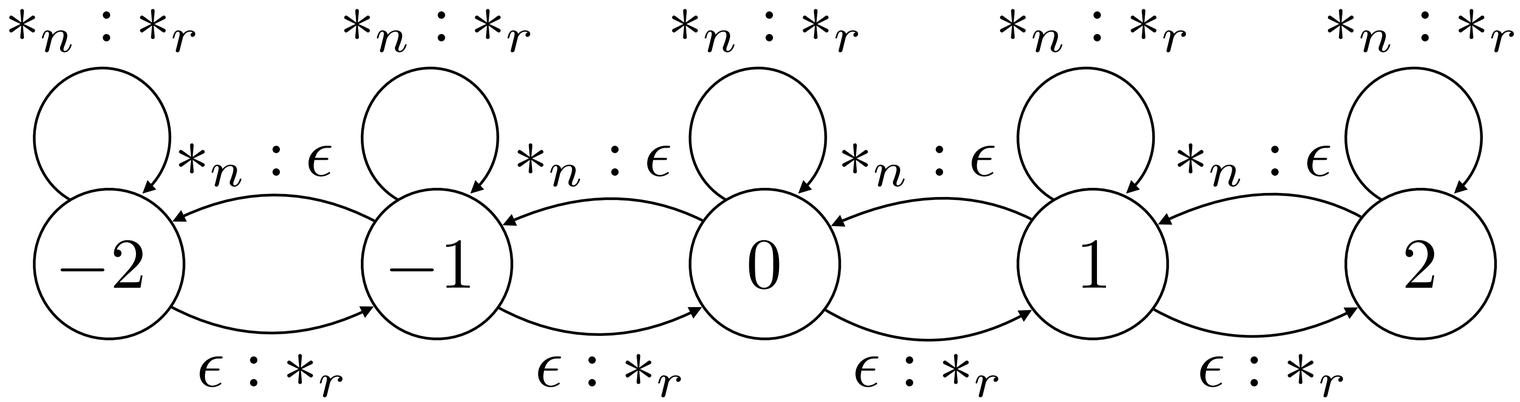
WFST cascade

- Transition WFSA
  - 6-gram LM built with OpenGrm (Roark et al., 2012)
- Emission WFST
  - Supports all substitutions, insertions and deletions

Emission model

- Needs to support substitutions, insertions and deletions
- Fixed limit on delay: |# of insertions - # of deletions|





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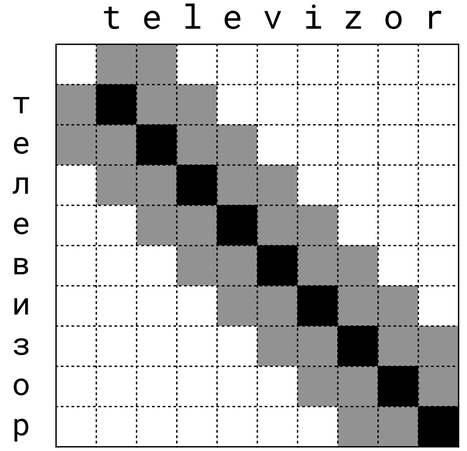
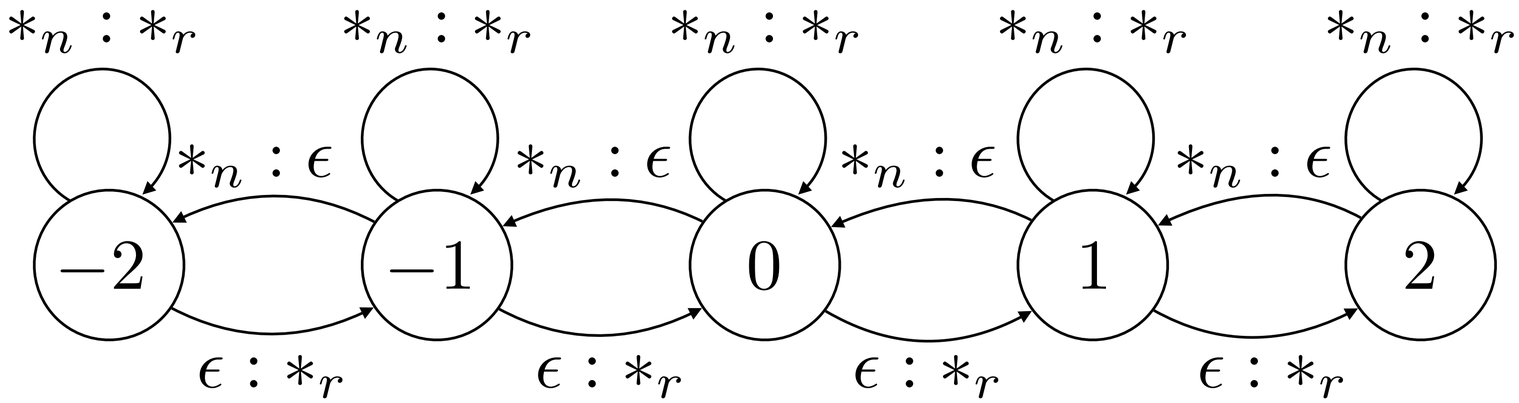




WFST cascade

- Transition WFSA
  - 6-gram LM built with OpenGrm (Roark et al., 2012)
- Emission WFST
  - Supports all substitutions, insertions and deletions
- Trained with EM algorithm
  - OpenFst (Allauzen et al., 2007)
  - Speedup tricks: stepwise training, curriculum learning, pruning…

Datasets

- Arabic: LDC BOLT dataset (Bies et al., 2014)
  - Arabizi SMS/chat dialogs, converted to CODA (Habash et al., 2012)

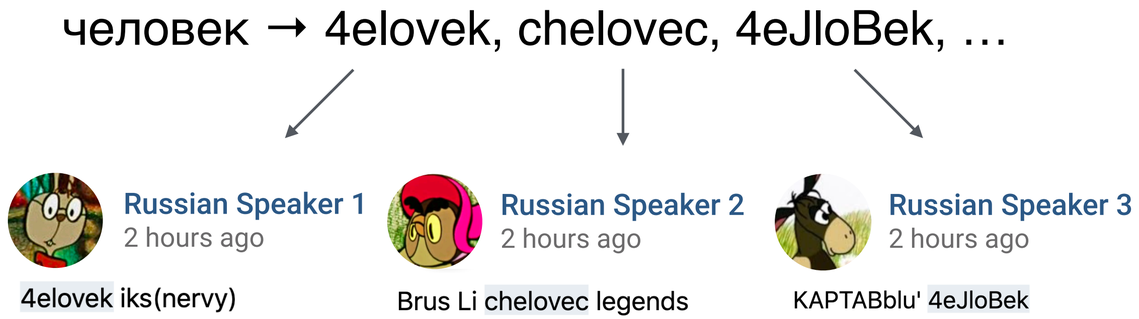
Saba7 el 5eir!
Ezayeeky?

- Kannada: Dakshina dataset (Roark et al., 2020)
  - Kannada Wikipedia, romanizations elicited from native speakers

- Russian:
  - Romanized: collected and partly annotated data from social media
  - Native: Taiga corpus (Shavrina & Shapovalova, 2017), comments in political forums

Russian data

- Romanizations of common words used as queries (Darwish, 2014)



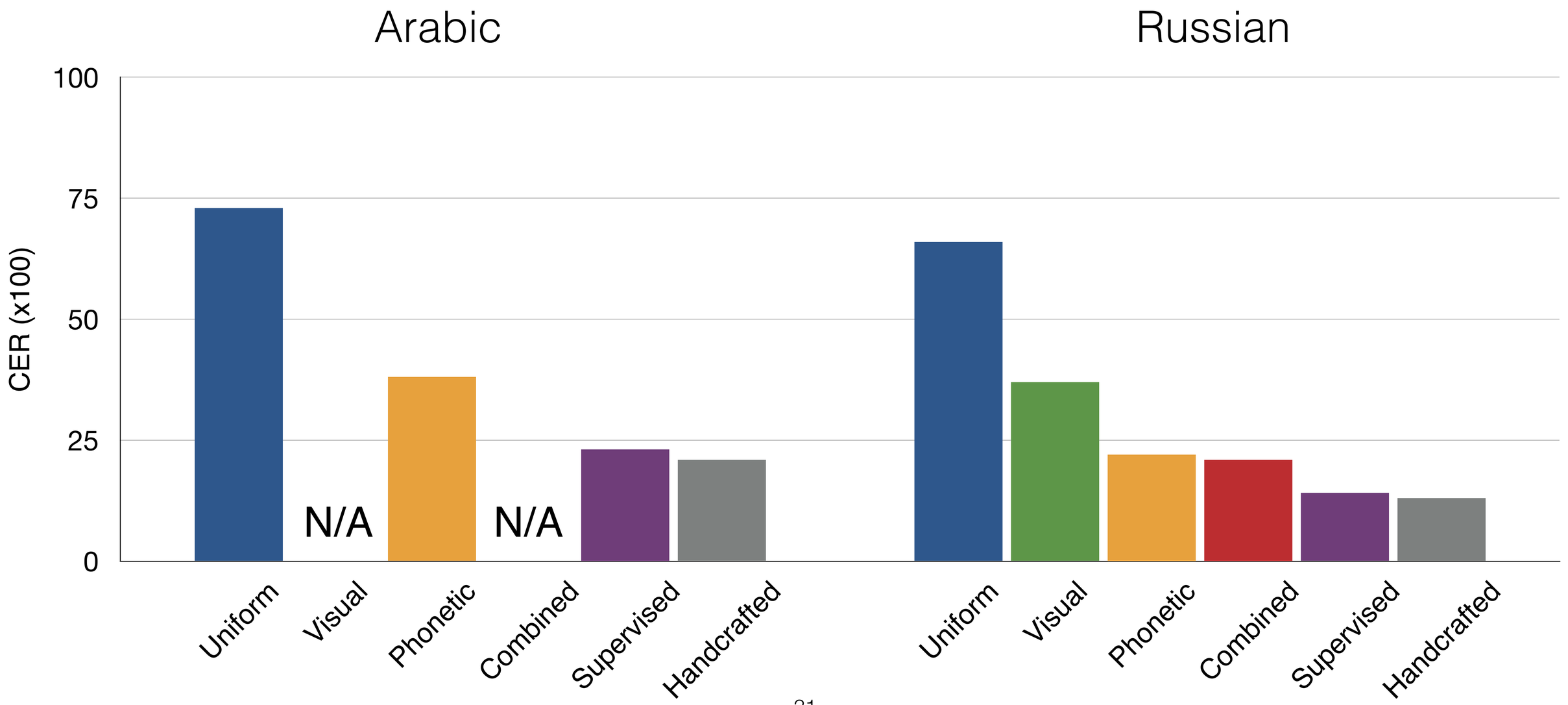
- Annotated validation and test with minor error correction

Source: proishodit s prirodoy 4to to very very bad

Filtered: proishodit s prirodoy 4to to <…>

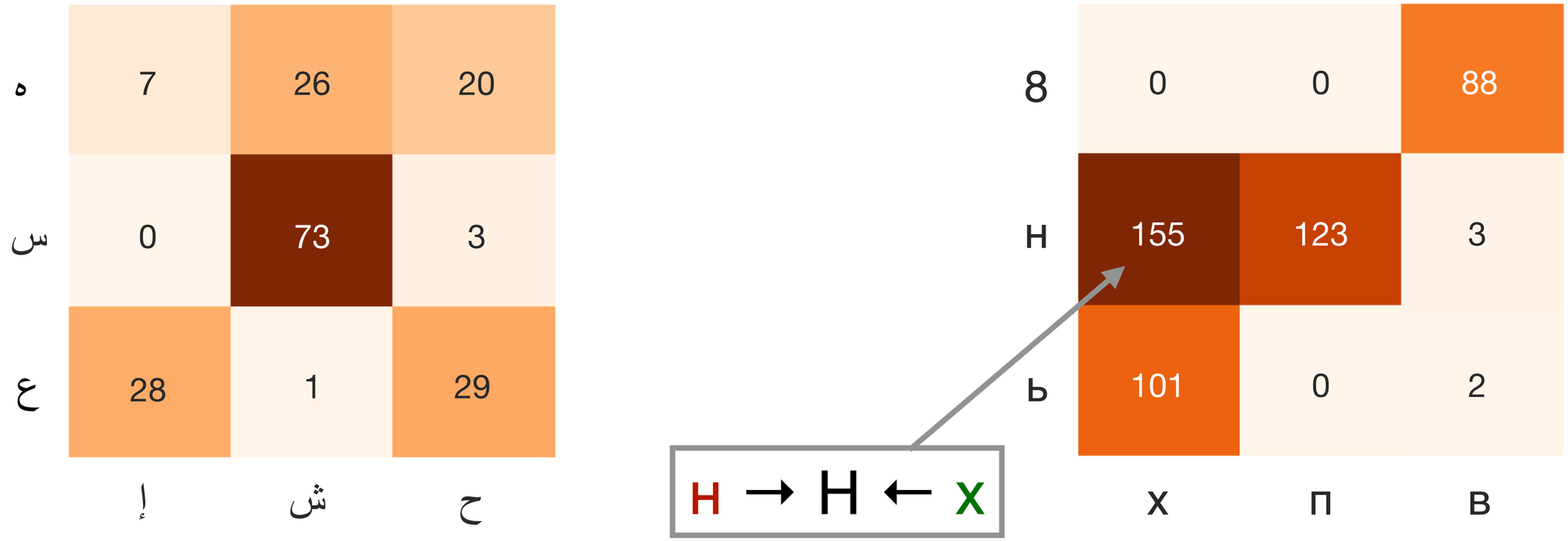
Target: происходит с природой что-то <…>

WFST results



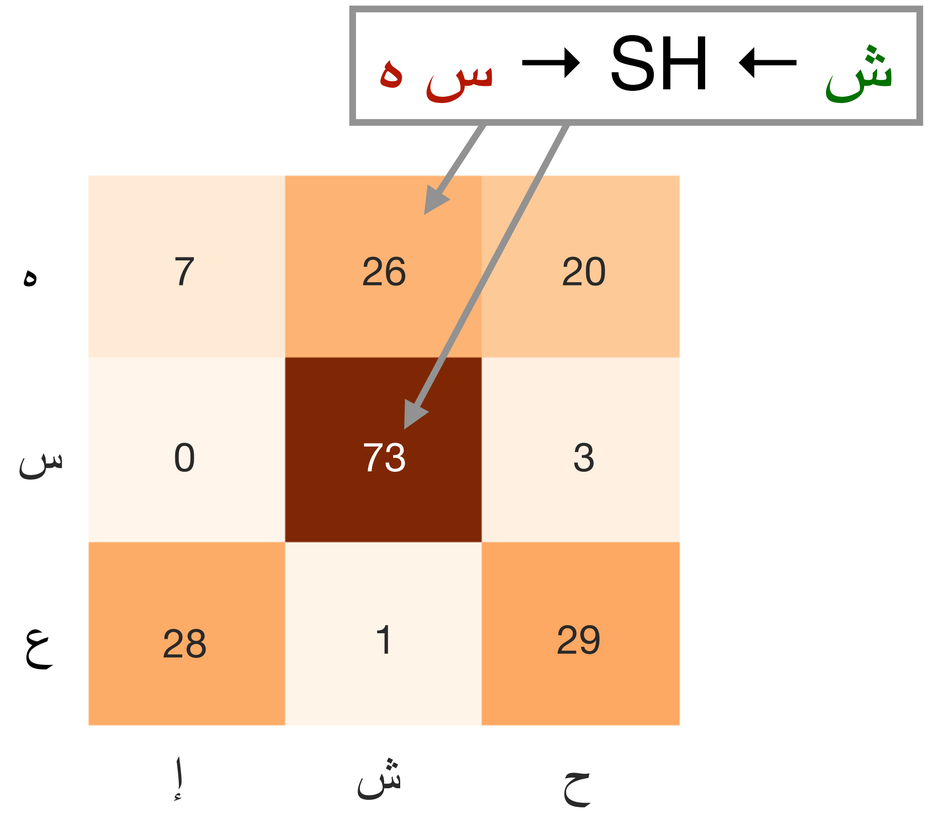
WFST error analysis

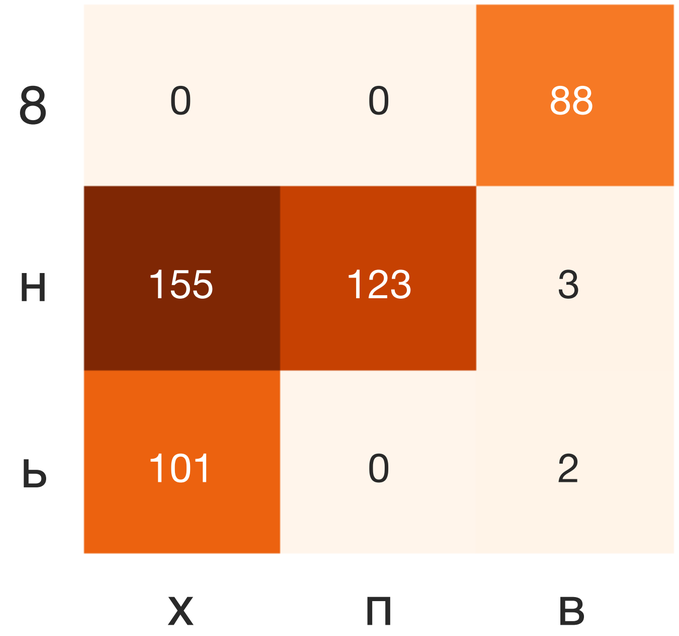
- Incorrect choice of plausible de-romanization (e.g. visual instead of phonetic)



WFST error analysis

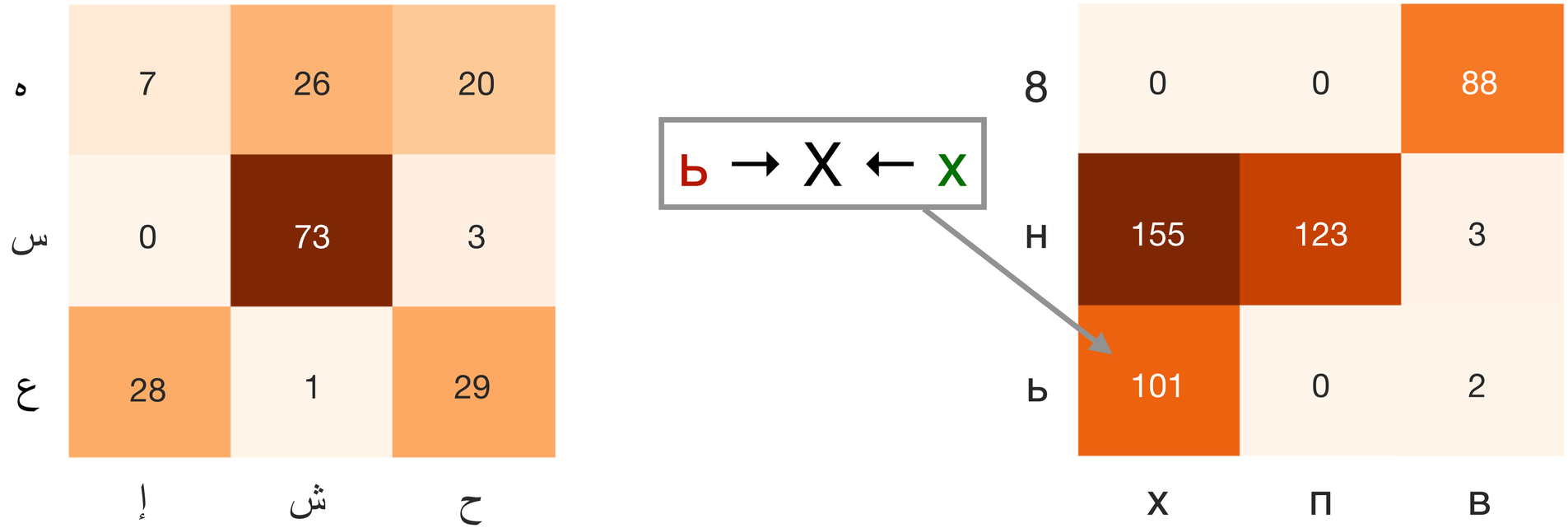
- Inability to handle digraphs like SH





WFST error analysis

- Distracted by spurious mappings in priors



Model classes

WFSTs are structured

- ✓ Easy to encode constraints
- ✓ Can learn from small data
- ✗ Slow exact maximization
- ✗ Weak n-gram language model

Seq2seqs are powerful

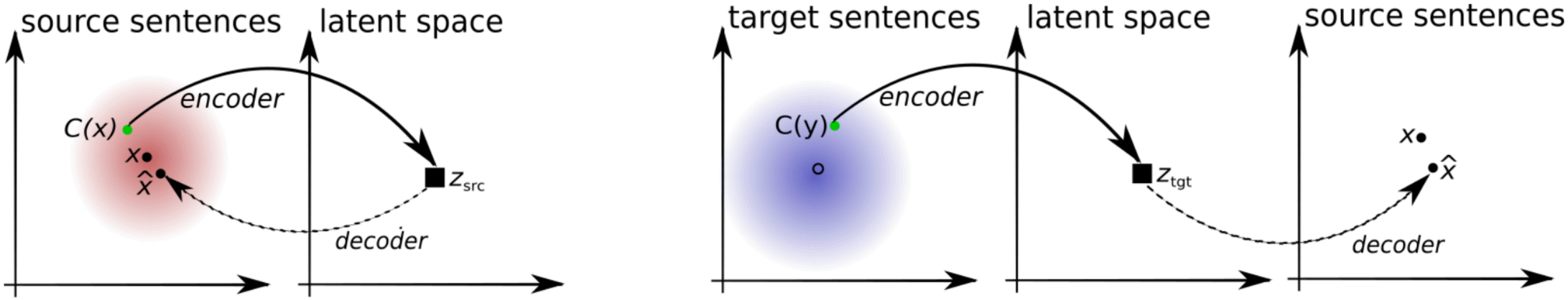
- ✓ Strong language model
- ✓ Faster batch processing
- ✗ Need large training data
- ✗ Hallucinations and search errors

In our case, both are trained unsupervised!

M Ryskina, E Hovy, T Berg-Kirkpatrick, MR Gormley. Comparative Error Analysis in Neural and Finite-state Models for Unsupervised Character-level Transduction. SIGMORPHON 2021.

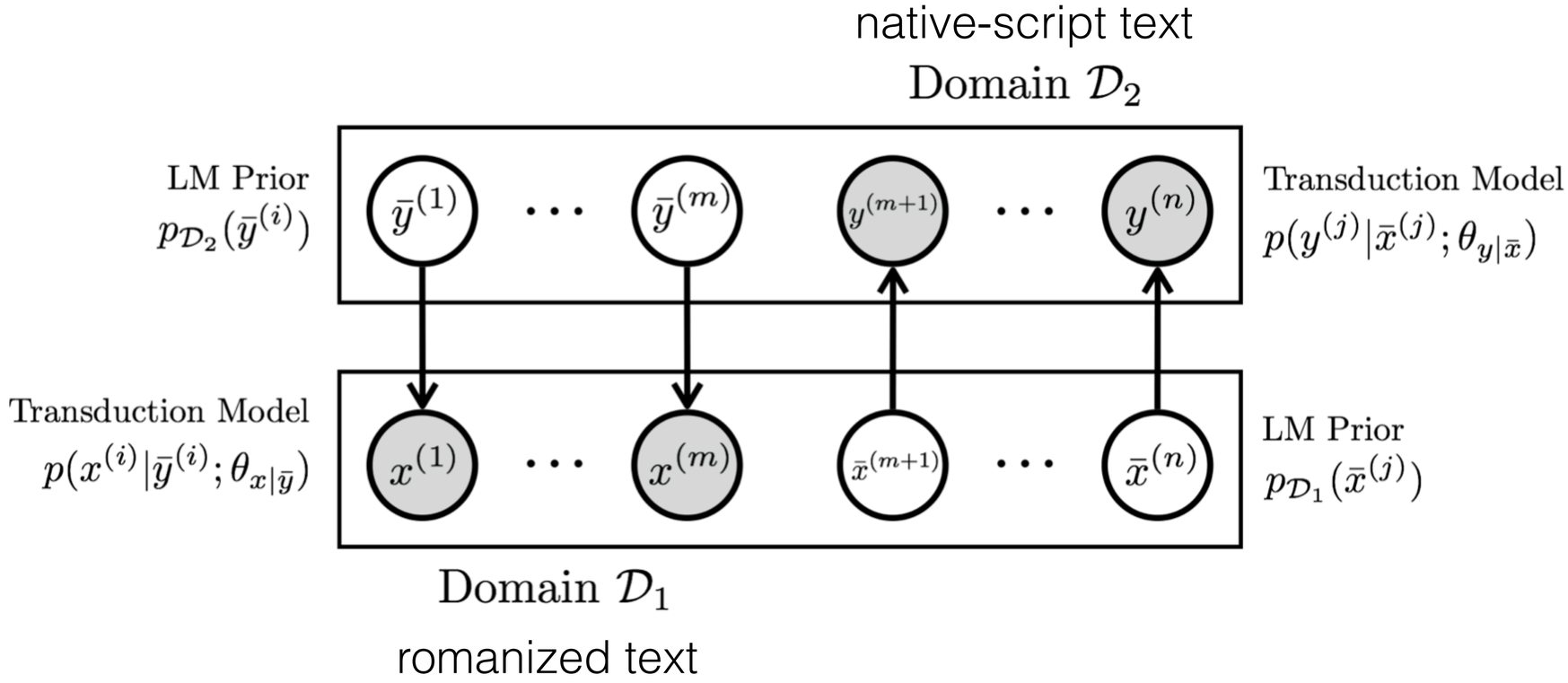
Unsupervised seq2seq

- Unsupervised neural machine translation (UNMT; Lample et al., 2018)
  - Auto-encoding: reconstructing a sentence from its noisy version
  - Back-translation: round trip through the latent space
  - Adversarial: discriminating between sentences in two domains



Unsupervised seq2seq

- Probabilistic formulation of UNMT: deep latent sequence model (He et al., 2020)

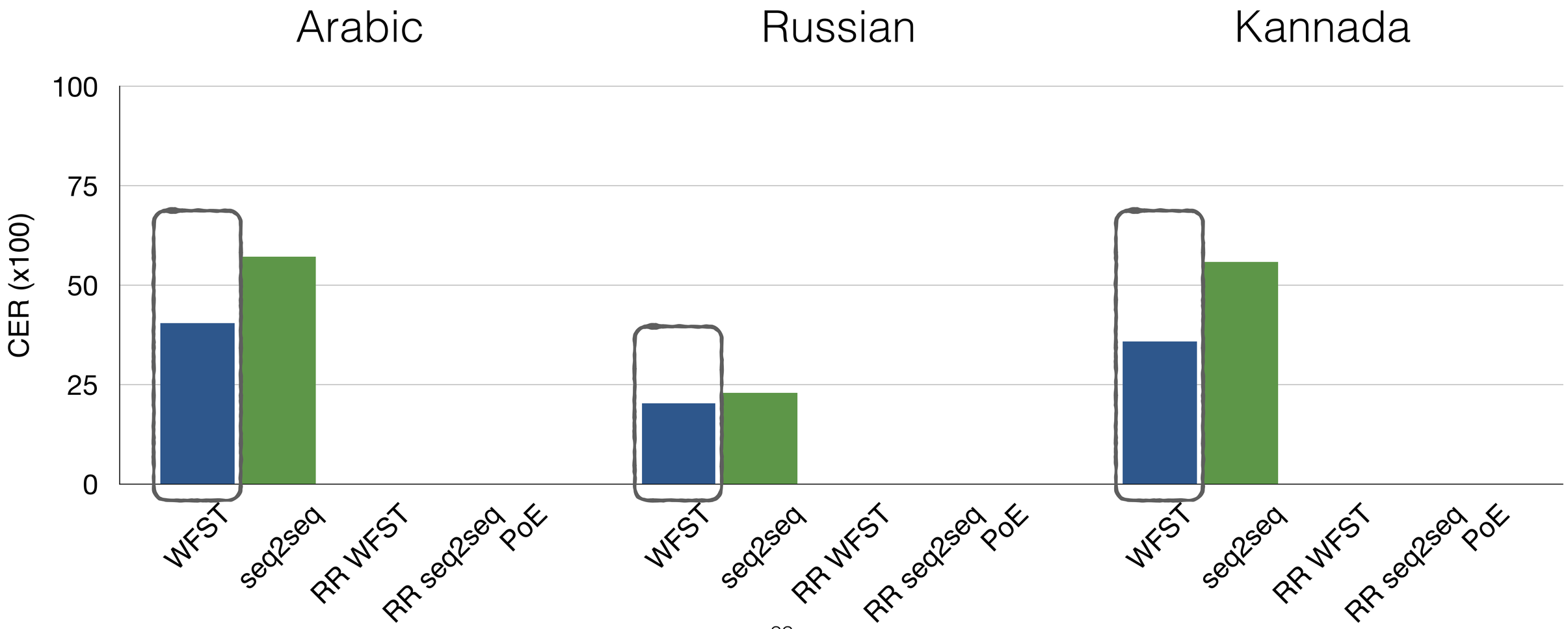


Model combinations

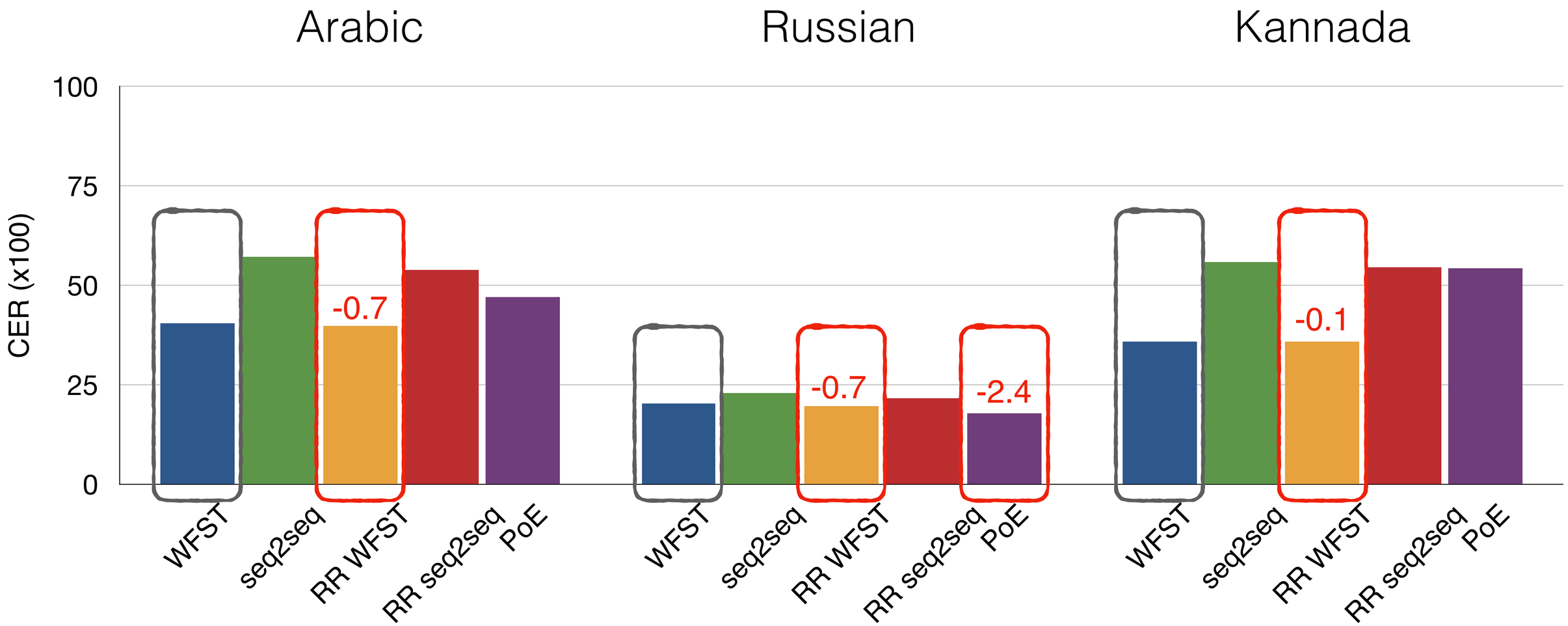
- Reranking
  - M1 generates top k candidate outputs
  - M2 selects the highest-scoring candidate
- Product of experts
  - Beam search on the WFST lattice
  - WFST arcs reweighted with Seq2seq softmax at the corresponding timstep
  - Deletions of input characters are not reweighted
  - Candidates are grouped by consumed input length
- We train the models separately and combine at test time

Results

Base models are trained on different amounts of data!



Results


Arabic
Russian
Kannada
CER (x100)
100
75
50
25
0
-0.7
-0.7
-2.4
-0.1
WFST
seq2seq
RR WFST
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PoE
WFST
seq2seq
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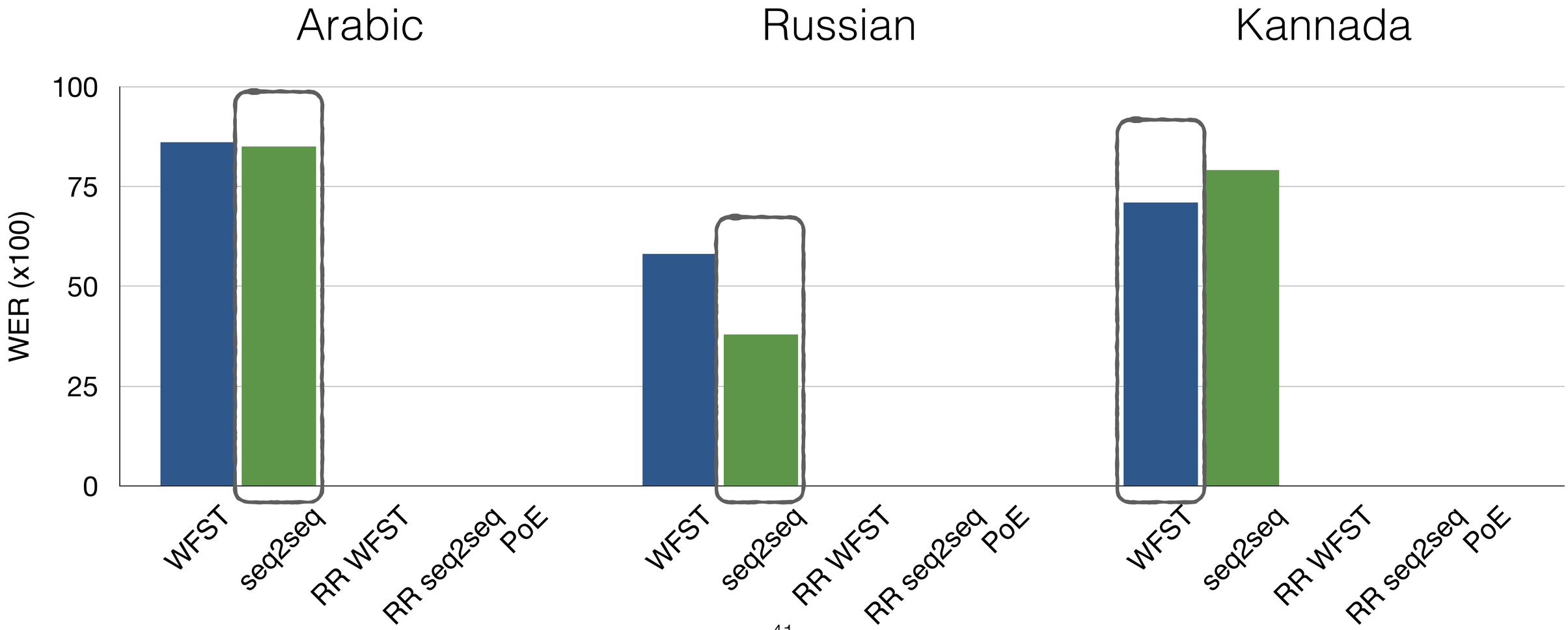
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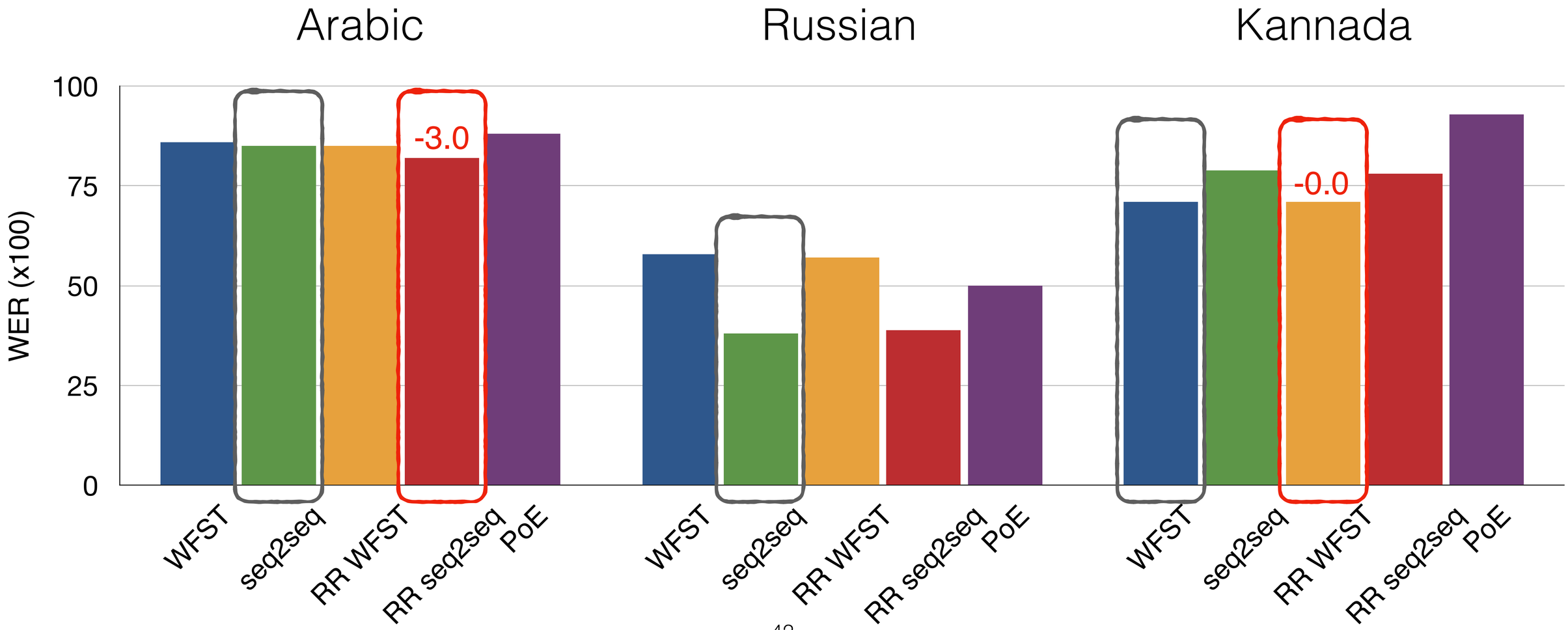
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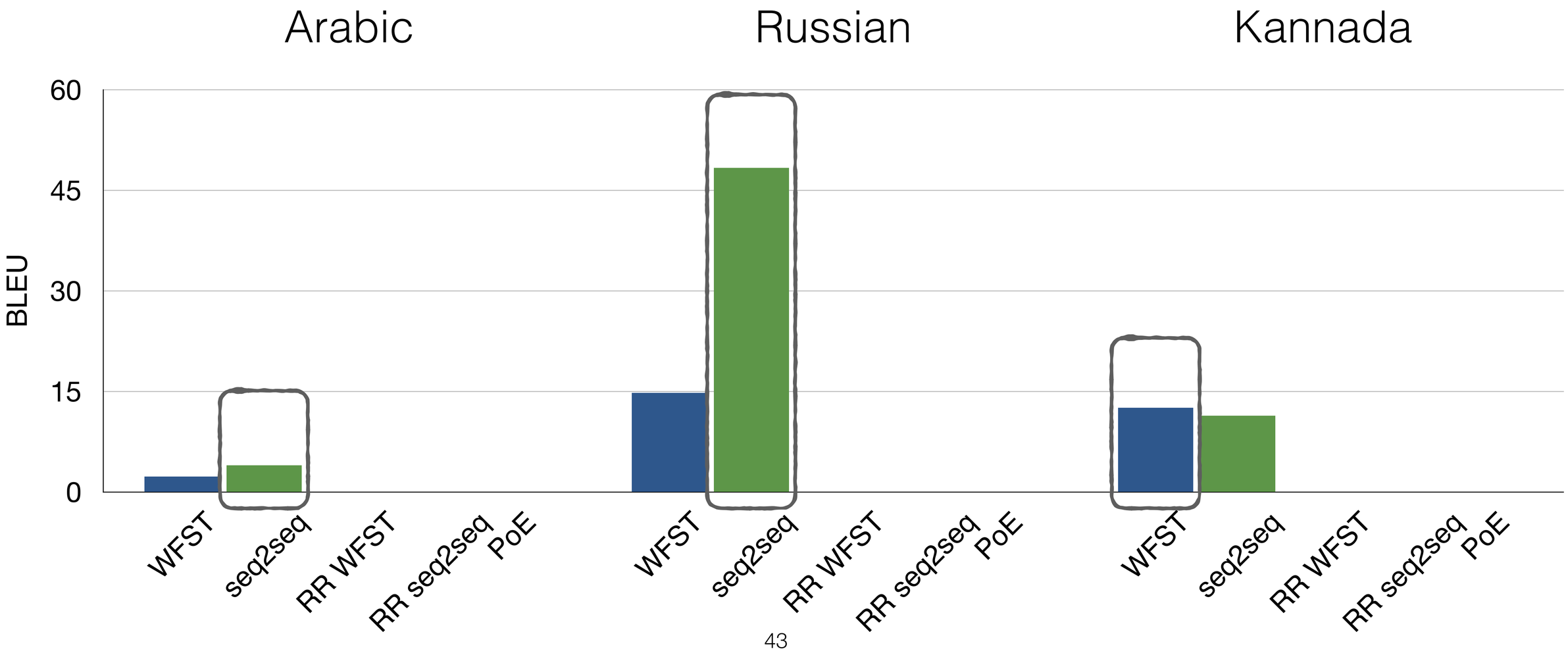
Arabic
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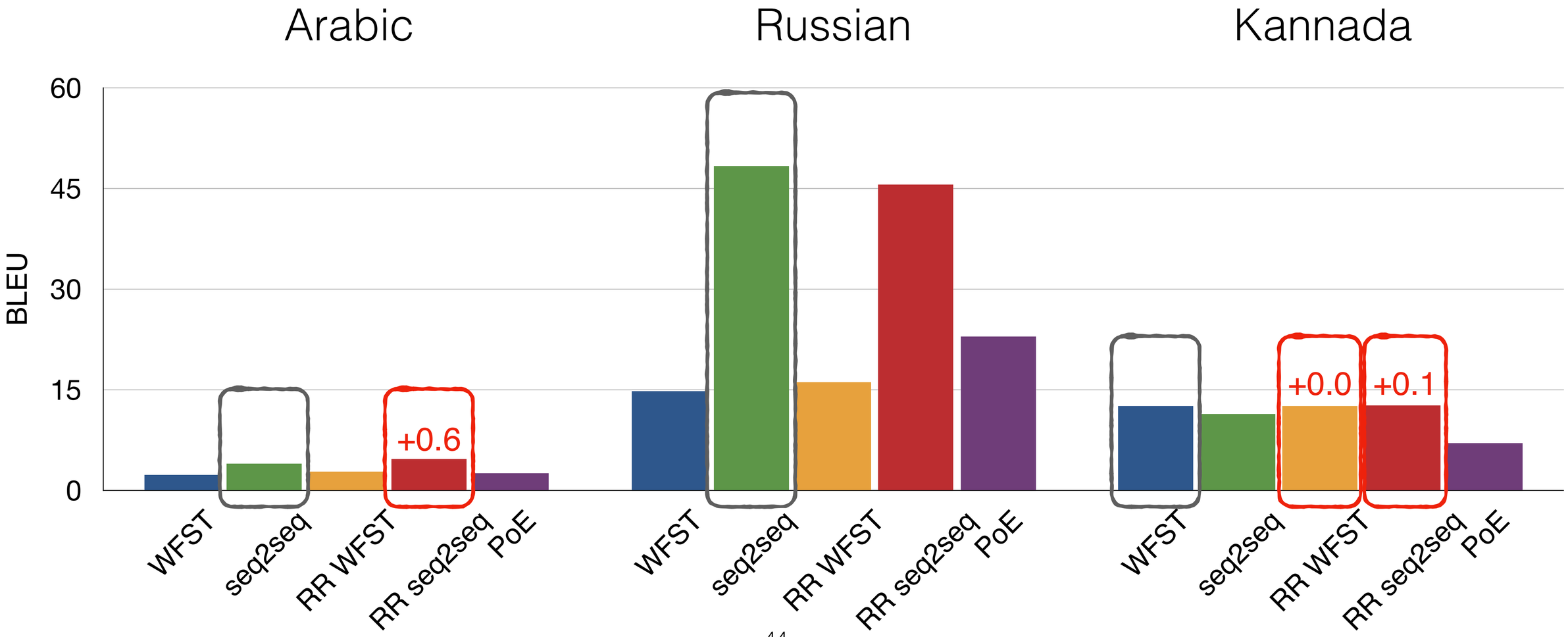
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RR seq2seq
PoE
WFST
seq2seq
RR WFST
RR seq2seq
PoE
WFST
seq2seq
RR WFST
RR seq2seq
PoE

Error analysis

Input	kongress ne odobril biudjet dlya osuchestvleniye "bor'bi s kommunizmom" v yuzhniy amerike.	
Ground truth	конгресс не одобрил бюджет для осуществления "борьбы с коммунизмом" в южной америке.	kongress ne odobril bjudžet dlja osuščestvlenija "bor'by s kommunizmom" v južnoj amerike.
WFST	конгресс не одобрил виудет дла осусчествлениые "бор#би с коммунизмом" в уузнани америке.	kongress ne odobril viudet dla osusčestvleniye "bor#bi s kommunizmom" v uuznani amerike.
Reranked WFST	конгресс не одобрил видет дела осусчествлениые "бор#би с коммунизмом" в уузнани америке.	kongress ne odobril videt dela osusčestvleniye "bor#bi s kommunizmom" v uuznani amerike.
Seq2Seq	конгресс не одобрил бы удивительно с коммунизмом" в южный америке.	kongress ne odobril by udivitel'no s kommunizmom" v južnyj amerike.
Reranked Seq2Seq	конгресс не одобрил бюджет для осуществление "борьбы с коммунизмом" в южный америке.	kongress ne odobril bjudžet dlja osuščestvlenie "bor'by s kommunizmom" v južnyj amerike.
Product of experts	конгресс не одобрил бидет для а осуществлениые "борьбы с коммунизмом" в уузник амери	kongress ne odobril bidet dlja a osuščestvleniye "bor'by s kommunizmom" v uuznik ameri

#=UNK

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Input	kongress ne odobril biudjet dlya osuchestvleniye "bor'bi s kommunizmom" v yuzhniy amerike.	
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Hallucination

Incorrect but faithful

High-level takeaways

- Model combinations still suffer from search issues

Source: eto uzhe (strashno skazat') stariy rolik.

Target: это уже (страшно сказать) старый ролик

Gloss: ‘By now this is (I’m almost afraid to say it) an old video’

Final beam hypotheses and reranker scores:

456.7, единая россия уже #страшно сказать) старый
502.0, единоросы уже #страшно сказать) старый рол
482.0, единороссы уже #страшно сказать) старый ро
456.8, единую россию уже #страшно сказать) старый
449.8, единой россии уже #страшно сказать) старый

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‘United Russia’

High-level takeaways

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Gloss: ‘By now this is (I’m almost afraid to say it) an old video’

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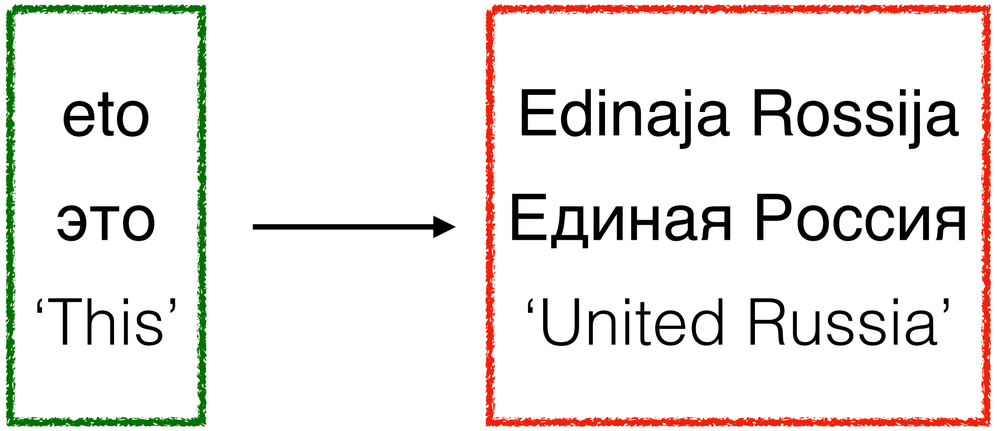
High-level takeaways

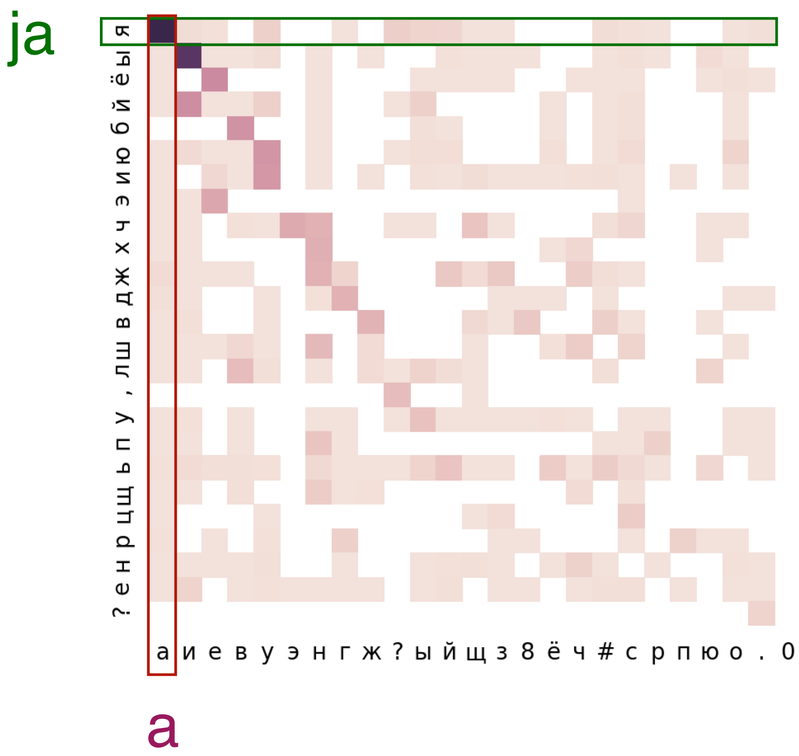
- Seq2seq is more sensitive to distributional shifts
  - Remember that our Cyrillic data comes from political discussion groups
  - 25% of common word-level errors in seq2seq are of this type!



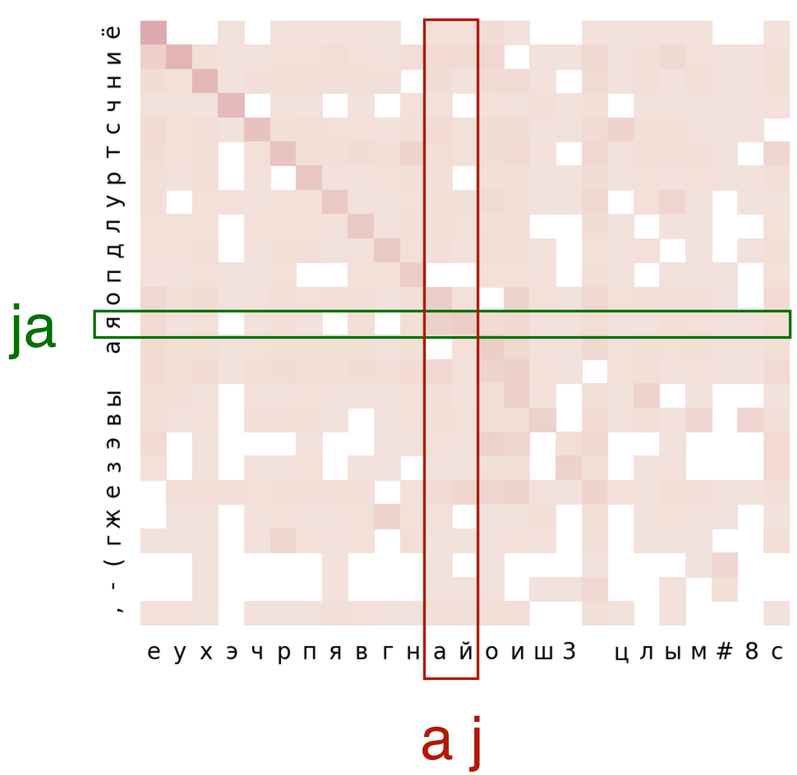
High-level takeaways

- WFST makes more repetitive errors
  - Suggests that WFST outputs might be easier to correct with rule-based postprocessing

WFST



seq2seq



Future work

- Combining unsupervised finite-state and neural models at training time
  - Joint training of two separate models
  - Holistic structural combinations
- Analysis of user preferences
  - Users tend to be consistent in their preferences
  - Substitution choices can reveal user background
  - Might want to obscure these attributes for privacy reasons
- Readability analysis instead of automated metrics

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