Designing finite-state morphological transducers for Kypchak languages

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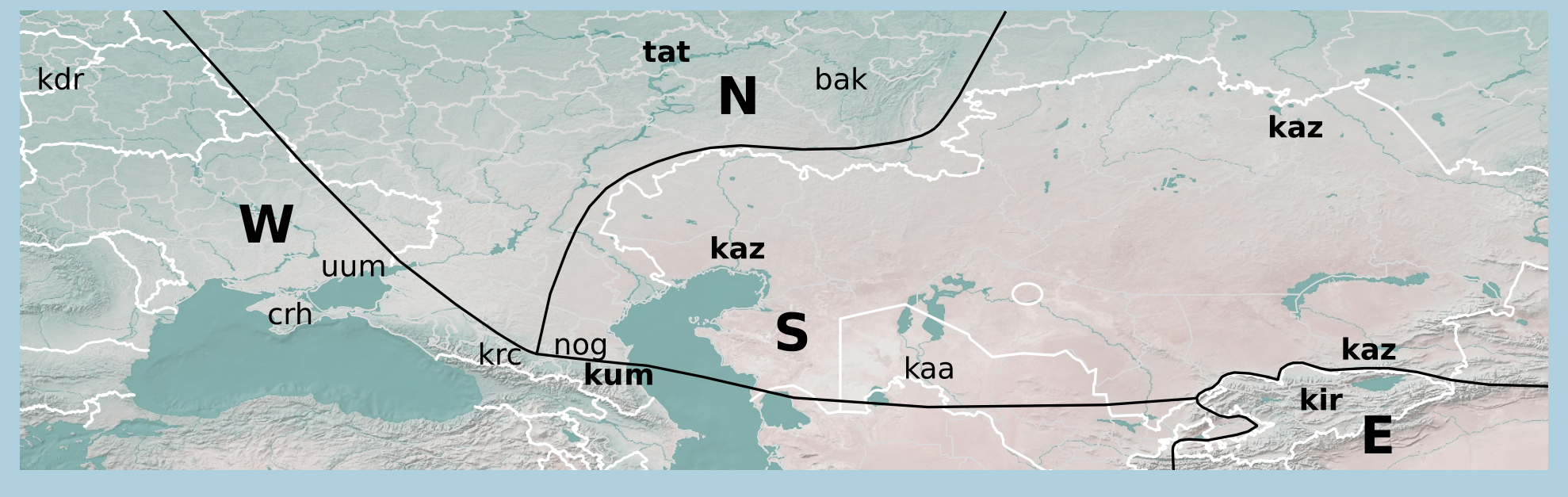
Kypchak languages



- Turkic languages (SOV, agglutinative, vowel harmony)

	Kyrgyz	**Kazakh**	**Tatar**	**Kumyk**
	/qɯrʁɯz/	/qɑzɑq/	/tɒtɑr/	/qumuq/
classification	Eastern	Southern	Northern	Western
population of speakers				
number	3M	8M-12M	5.4M	430K
primary	Kyrgyzstan	Kazakhstan	Tatarstan	Dagestan
secondary	China, etc.	China, Mongolia	Bashqortostan	—
external influences				
Mongolic	moderate	moderate	light	light
Oghuz	—	—	light	moderate
Persian	heavy	heavy	heavy	heavy
Russian	heavy	heavy	heavy	heavy

Morphological transducers

Morphological transducers

- Efficient (in speed & size) models of a language's morphology
- Take a surface form, and produce valid lexical form(s)
- Take a lexical form, and produce valid surface form(s)
  алдым ↔ ал<v><tv><ifi><p1><sg>, алд<n><px1sg><nom>

Transducers for Turkic languages

- Turkish (Çöltekin, 2010 & 2014; Oflazer, 1994)
- Crimean Tatar (Altıntaş, 2001)
- Turkmen (Tantuğ et al., 2006)
- Kazakh (Бекманова & Махимов, 2013)
- our Kyrgyz, Kazakh, Tatar, Kumyk: all GPL (=free and open)!

Framework: HFST

- Reimplements Xerox FST formalisms (lexc & twol)
- Also provides a wrapper around popular free/open-source FST toolkits: SFST, OpenFST, and Foma

Approach

- morphotactics implemented in lexc
- morphophonology implemented in twol
- compiled separately; compose-intersected to single transducer
  алдым ↔ ал>{D}{I}>м ↔ ал<v><tv><ifi><p1><sg>
  алдым ↔ алд>{I}м ↔ алд<n><px1sg><nom>

Further information

- Part of **Apertium Turkic** project:
  http://wiki.apertium.org/wiki/Apertium_Turkic
- Transducers available **live** at turkic.apertium.org
- **Source code** available from Apertium's svn repo
- Turkic RBMT **mailing list** (>25 subscribers):
  apertium-turkic@lists.sourceforge.net
  Feel free to post in any language!
- See our papers in LREC proceedings
  (2012: Kyrgyz, 2014: Kazakh, Tatar, Kumyk)
- And feel free to contact the authors any time!

Example output

Gloss

(1)	Кудай	Өзү	жаратканынын	баарына	карап,		өтө	жакшы	экенин	көрдү.
	Құдай	Өзінің	жаратқандарының	бәріне	қарап,		өте	жақсы	екенін	көрді.
	Аллаh	Үзе	яраткан	нәрсәләргә	карап,	аларның	бик	яхшы	икәнен	күрде.
	Аллагь	Оьзю	яратгъан	затлагъа	къарап,	олар	бек	яхшы	экенин	гёрген.
	God	own-his	created	[everything/thing-s]-to	looked.at,	they/their	very	good	being	saw.

'*God looked at everything he had created and saw that it was very good.*' (Bible, Genesis 1:31)

Output

Kyrgyz (kir)	**Kazakh** (kaz)	**Tatar** (tat)	**Kumyk** (kum)
Кудай Өзү жаратканынын баарына карап, өтө жакшы экенин көрдү.	Құдай Өзінің жаратқандарының бәріне қарап, өте жақсы екенін көрді.	Аллаh Үзе яраткан нәрсәләргә карап, аларның бик яхшы икәнен күрде.	Аллагь Оьзю яратгъан затлагъа къарап, олар бек яхшы экенин гёрген.
Кудай<n><nom> Өз<prn><ref><px3sp><nom> жарат<v><tv><ger_past><px3sp><gen> баары<prn><qnt><px3sp><dat> кара<v><tv><gna_perf> ,<cm> — өтө<adv> жакшы<adj> э<cop><ger_past><px3sp><acc> көр<v><tv><ifi><p3><sg> .<sent>	Құдай<n><nom> Өз<prn><ref><px3sp><gen> жарат<v><tv><ger_past><pl><px3sp><gen> бәрі<prn><qnt><px3sp><dat> қара<v><tv><gna_perf> ,<cm> — өте<adv> жақсы<adj> е<cop><ger_past><px3sp><acc> көр<v><tv><ifi><p3><sg> .<sent>	Аллаh<n><nom> Үз<prn><ref><px3sp><nom> ярат<v><tv><gpr_past> нәрсә<n><pl><dat> кара<v><tv><gna_perf> ,<cm> алар<prn><pers><p3><pl><gen> бик<adv> яхшы<adj> и<cop><ger_past><px3sp><acc> күр<v><tv><past><p3><sg> .<sent>	Аллагь<n><nom> Оьз<prn><ref><px3sp><nom> ярат<v><tv><gpr_past> зат<n><pl><dat> къара<v><tv><gna_perf> ,<cm> олар<prn><pers><p3><pl><nom> бек<adv> яхшы<adj> э<cop><ger_past><px3sp><acc> гёр<v><tv><past><p3><sg> .<sent>

Tagset

<n>	Noun	<iv>	Intransitive	<nom>	'Nominative'	<sent>	Sentence	<gna_perf>	Verbal adverb (Perfect)
<v>	Verb	<tv>	Transitive	<gen>	Genitive	<past>	Past (General)		
<prn>	Pronoun	<p3>	Third person	<acc>	Accusative	<ifi>	Past (Eyewitness/Recent)	<gpr_past>	Verbal adjective (Past)
<det>	Determiner	<pl>	Plural	<dat>	Dative				
<adj>	Adjective	<ref>	Reflexive	<qnt>	Quantifier	<px3sp>	3rd person poss. (Singular/Plural)	<ger_past>	Verbal noun (Past)
<adv>	Adverb	<pers>	Personal	<cm>	Comma				

Morphophonology

Desonorisation (kaz & kir)

- {N} desonorises to д after a consonant
  алма-{N}{I} → алманы '*apple*–ACC'
  сыр-{N}{I} → сырды '*secret*–ACC'
- {L} desonorises to д after cons. of sonority ≤ /l/
  сыр-{L}{A}р → сырлар '*secret*–PL'
  кыз-{L}{A}р → кыздар '*girl*–PL'

```
"L Desonorisation"
%{L%}:д <=> :VoicedLowSonCns %>: __ ;

"N Desonorisation"
%{N%}:д <=> :VoicedCns %>: __ ;
```

Epenthesis

- Turn {y} into a harmonised high vowel when a vowel doesn't follow the following consonant:
  мур{y}н → мурун '*nose*'
  мур{y}н+{I}м → мурдум '*my nose*'

```
%{y%}:Vy <=> [ :LastVowel :Cns* :Cns ]/[:0] __
                [ :Cns [ .#. | :Cns ] ]/[ :0 | %>:] ;
 where Vy in ( и ү и и ү ы ы у у ы у у )
LastVowel in ( и ү е э ө я а ё о ы ю у )
            matched ;
```

Other uses

- HFST transducers are trivially converted to **spell checkers**
- Segmenter, e.g. көргөзгөндөрдөнсүңбү :
  көр>{G}{A}з>{G}{A}н>{L}{A}р>{D}{A}н>с{I}ң>{B}{I}

Morphotactics

Morphological & orthographical words

- өнүктүрөбүзбү ? '*will we develop [it]?*'
  өнүк<v><tv><caus><aor><p1><pl>+бы<qst>
- келатсаң '*if you come*'
  кел<v><iv><prc_impf>+жат<vaux><gna_cnd><p2><sg>

Irregular [noun + possessive + case] forms

- Some combinations of possessive + case morphemes are unpredicted (i.e., not formed simply by concatenation and application of phonology):

case	form	1SG	2SG	3SP
nominative	—	-(I)м	-(I)ң	-(с)I
accusative	-NI	-(I)мдI	-(I)ңдI	**-(с)Iн**
genitive	-NIн	-(I)мдIн	-(I)ңдIн	-(с)IнIн
locative	-DA	-(I)мдА	-(I)ңдА	**-(с)IндА**
ablative	-DAн	-(I)мдАн, **-(I)мАн**	-(I)ңдАн, **-(I)ңАн**	**-(с)IнАн**
dative	-GA	**-(I)мА**	**-(I)ңА**	**-(с)IнА**

A,I,N,D,G have various allophones; (I) null after vowels; (c) null after cons.

- underlying <px3sp> form used: {s}{I}{n}
- {s} and {n} default to с and н; rules map to null by context
- morphophonology more complicated, morphotactics simpler

Noun-noun compounds

- a N-N compund type: N2 has <px3> and related morphology
  e.g., аба ырайы<n><loc>: аба ырайында, *аба ырайыда

```
LEXICON N-INFL-3PX-COMPOUND
%<n%>:%>%{S%}%{I%}%{n%} GEN-POS ;

LEXICON Nouns
аба% ырайы:аба% ырай N-INFL-3PX-COMPOUND ;
                                        ! "weather"
чакыруу% кагазы:чакыруу% кагаз N-INFL-3PX-COMPOUND
                                    ; ! "invitation"
```

Orthography-phonology mapping issues

Ambiguous characters

- Have front- and back-vowel readings in native words

	letters	values	examples
kaz	и, у, ю	/əj, əw, jəw/ /əj, əw, jəw/	қиюда '*chopping down*' киюде '*getting dressed*'
tat	е	э / C _ /j/+ы /j/+э	дәресләр '*lessons*' еллар '*years*' егетләр '*boys*'
kum	ё, ю	/ø, y/ / C _	гюнлер '*days*' гёзлер '*eyes*'
		/jø, jy/	юреклер '*hearts*' ёнкюлер '*darlings*'
		/jo, ju/	юлдузлар '*stars*' ёллар '*roads*'

- solution: hairy twol rules cover majority of examples
- unaccounted-for words get a harmony-forcing character
- adjust rules for harmony-forcing characters

Loanwords

- Letters that represent front vowels in native words may represent "back" vowels in Russian words

	native word example	Russian word example
kaz	елдің '*country's*'	Назарбаевтың '*Nazarbayev's*'
tat	галимнәр '*scientists*'	артистлар '*artists*'
kum	сёзлер '*words*'	самолётлар '*airplanes*'

- solution: separate continuation lexicon (messy rules)

```
LEXICON N1-RUS
:%{☭%} N1 ;

LEXICON Nouns
артист:артист N1-RUS ; !  "artist"
галим:галим N1 ; !  "scientist"
```

Acronyms and numerals

- twol rules handle phonology for spelt-out words
  отыздан '*from thirty*', бестен '*from five*'
- no phonological triggers available in numerals (incorrect phonological triggers in acronyms)
  30-дан '*from 30*', 5-тен '*from 5*'
- solution: phonology-triggering characters
- simplified: e.g., {c} for all voiceless ostruents

```
4:4%{э%}%{c%} NUM-DIGIT ; !  "төрт"
5:5%{э%}%{c%} NUM-DIGIT ; !  "бес"
3%0:3%0%{а%}%{з%} NUM-DIGIT ; !  "отыз"
```

й + vowel letters

- [а о у] become [я ё ю] after й and й deletes
- й incorporated into the context of many rules
- additional rules to change the characters and delete original й

```
"Deletion of й before yoticised vowels"
й:0 <=> __ [ :YotVow ]/[ :0 | %>: ] ;
```

A resulting messy twol rule

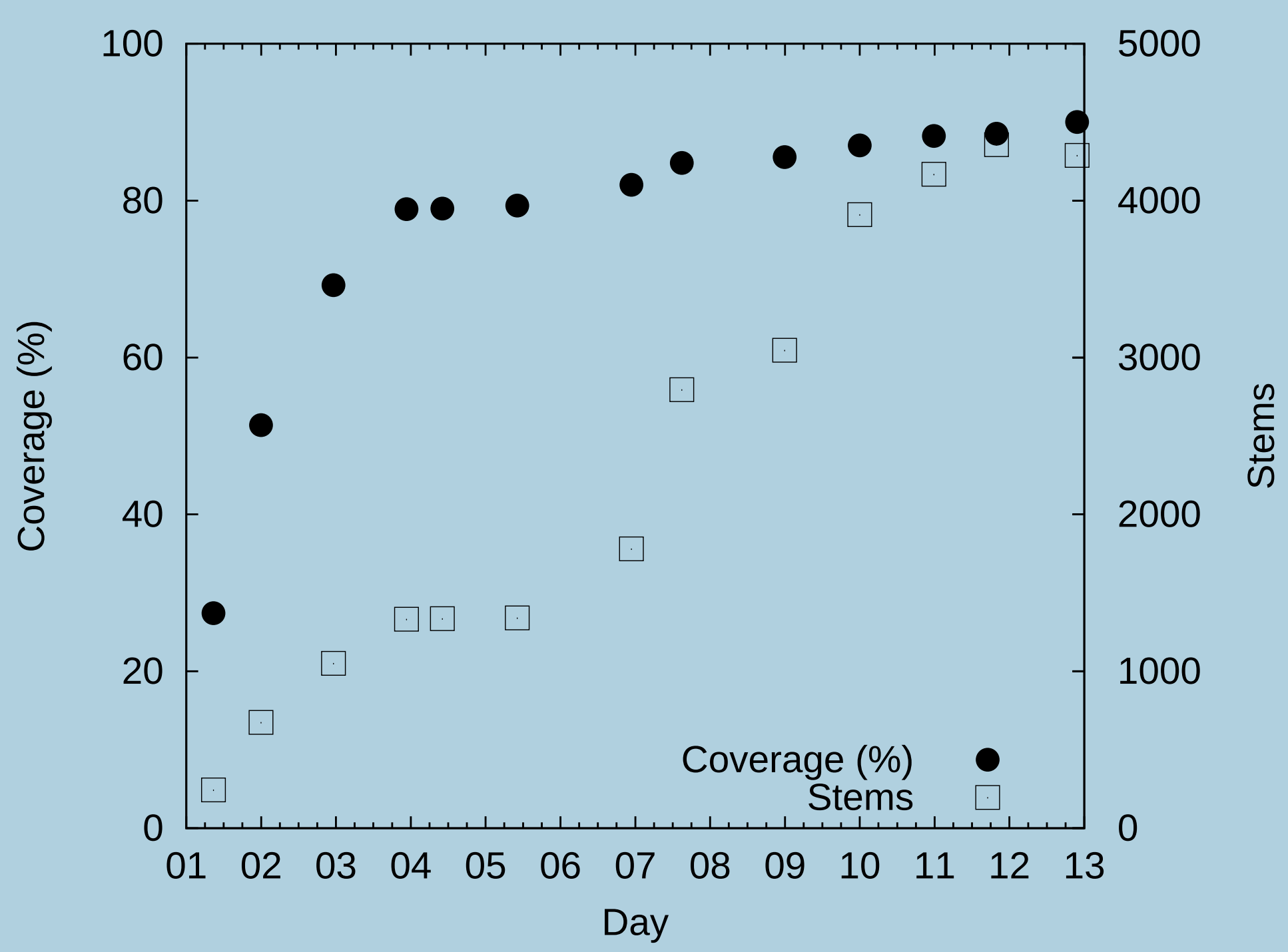
```
RdYotVow = ё ю Ё Ю ;
AbstractVow = %{а%} %{э%} %{ү%} %{о%} ;

"A front unrounded harmony"
%{A%}:е <=>            [ [ :FrontVow | [ :Vow :ь ] ] :Cns :Cns* ]/:0 _ ;
                                     [ [ :RdVow :ь ] :Cns :Cns* ]/:0 _ ;
                  [ [ [ \[ .#. | :Vow ] ] :RdYotVow ] :Cns :Cns* ]/:0 _ ;
                  [ :RdYotVow й:0 :RdYotVow :Cns :Cns* ]/[ :0 - й:0 ] _ ;
           [[%{э%}:0|%{ү%}:0] :Cns* ]/[[ :0 - AbstractVow:  ]  | %-:  ]* _ ;
            except
                    [ :RdYotVow :Cns* %{☭%}:0 :Cns* ]/[ :0 - %{☭%}:0 ] _ ;
                                 [ :Cns :р %{☭%}:  %>:  :Cns* ]/:0 _ ;
                      [ [ :Vow - :RdYotVow ] :RdYotVow :Cns :Cns* ]/:0 _ ;
                                 [ :Vow ]/[ [ :0 - й:0 ] | %>:  ]  _ ;
```

Development effort

	Kyrgyz	Kazakh	Tatar	Kumyk
begun	Apr. 2011	Dec. 2010	Dec. 2011	Oct. 2013
80% cov.	Aug.? 2011	Aug. 2012	Aug. 2012	Oct. 2013
time	4 months	19 months	7 months	1 week

- (various periods of intermission, various rewrites)
- Kazakh transducer based on Kyrgyz transducer
- Kyrgyz transducer currently being rewritten based on insights gained while writing other Turkic transducers
- Kumyk transducer based on Kazakh, Tatar transducers: ~1 week to reach 80% coverage, +1 week to reach 90%



Categorisation

Adjectives

- morphologically distinct adjective classes
- most sources claim: adjectives can be used substantively and adverbially
- Other Turkic transducers: 0-derivation (overgenerates)
- but not all adjectives have all of the following: comparative forms, substantive readings, adverbial readings
- Our approach: categorisation
- if properly categorised, only correct forms are analysed and generated

Type	Gloss	<adj>(<comp>)	<adj>(<comp>)<subst>	<adj>(<comp>)<advl>
A1	'*good*'	яхшы (яхшырак)	яхшы (яхшырак)	яхшы (яхшырак)
A2	'*old*'	иске (искерәк)	иске (искерәк)	— (—)
A3	'*dead*'	үле (—)	үле (—)	— (—)
A4	'*basic*'	төп (—)	— (—)	— (—)

Adverbs

- Certain adverbs have special attributive and ablative forms
- Mostly time adverbs
- Some also have noun readings: regular ablative, other cases:

word gloss	бүгүн '*today*'	быйыл '*this year*'	кечээ '*yesterday*'	жана '*just now*'
<attr> form	бүгүнкү	быйылкы	кечээги	жанагы
<adv><abl> form	бүгүнтөн	быйылтан	кечээтен	жанатан
<n><abl> form	бүгүндөн	быйылдан	—	—

```
LEXICON ADV-WITH-KI-ABL

ADV ;
ADV-KI ;
ADV-ABL ;
```

Evaluation

Number of stems

Part of speech	Number of stems			
	Kyrgyz	Kazakh	Tatar	Kumyk
Noun	4582	2640	2795	2568
Verb	1193	1470	1143	386
Adjective	1211	754	816	219
Proper noun	5887	5701	5361	1443
Adverb	312	171	177	63
Numeral	66	63	63	44
Conjunction	77	46	45	13
Postposition	50	50	43	12
Pronoun	51	32	28	17
Determiner	64	39	34	9
Total:	13749	11224	10737	4845

Test corpora

	Wikipedia	News	Religion
Kyrgyz	Wikipedia	azattyk.org	Bible
Kazakh	Wikipedia	azattyq.org	Quran + Bible
Tatar	Wikipedia	tat.tatar-inform.ru	Quran + New Testament
Kumyk	—	yoldash.etnosmi.ru	Genesis + New Testament

Evaluation measures

- **Naïve coverage** - percentage of surface forms in a given corpus receiving ≥ 1 analysis
- **Mean ambiguity** - average number of analyses for each surface form found in analysed corpus
- **Precision** - probability that a provided analysis is valid
- **Recall** - probability that a certain valid analysis is among those provided by the transducer

Evaluation results

	Corpus	Tokens	Coverage (%)	Amb.
Kyrgyz	Wikipedia	5.3M	84.51 ± 2.27	3.56
	News	4.1M	91.43 ± 0.51	4.19
	Religion	215K	91.66 ± 1.81	3.99
(r54474)	Average		89.20 ± 3.48	3.91
Kazakh	Wikipedia	25.6M	85.61 ± 1.37	2.43
	News	3.8M	92.12 ± 2.72	2.88
	Religion	851K	92.49 ± 1.66	2.63
(r50547)	Average		90.07 ± 1.91	2.64
Tatar	Wikipedia	159K	86.35 ± 2.17	2.24
	News	5.2M	89.75 ± 0.07	2.30
	Religion	382K	91.25 ± 2.55	2.24
(r50260)	Average		89.12 ± 1.60	2.26
Kumyk	News	286K	91.10 ± 0.86	1.53
	Religion	227K	92.47 ± 1.03	1.53
(r50300)	Average		91.78 ± 0.94	1.53

- selected & proofed unique random surface forms from news corpora

Language	Forms	Precision (%)	Recall (%)
Kyrgyz	200	90.77	69.15
Kazakh	1000	98.61	57.98
Tatar	1000	95.03	85.65
Kumyk	500	96.57	69.11

Ongoing and future work

- Disambiguation, more stems, clean up transducers
- Machine translation between these languages
- Bring other Kypchak transducers to comparable performance: Qaraqalpaq, Bashqort, Nogay, Crimean Tatar
- Other Turkic lgs: Uzbek, Uyghur, Chuvash, Yakut, Tuvan, etc.