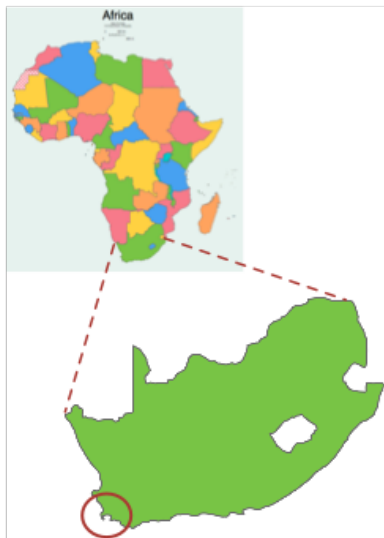


NLP for African (Nguni) languages

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Outline

- 1 Motivation
 - Context
 - Language 'crash course'
- 2 Corpus-based spellcheckers
 - Error detection for isiZulu and isiXhosa
 - Error correction for isiZulu and isiXhosa
 - Discussion
- 3 Rule-based NLG
 - What is CNL, NLG?
 - Generating basic sentences
 - Language learning exercises
- 4 Summary

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Motivation

- IsiZulu and isiXhosa most widely spoken languages in South Africa by first language speakers
- 23% or about 11 million people (isiZulu), 8 million (isiXhosa)
- Have very limited ICT support

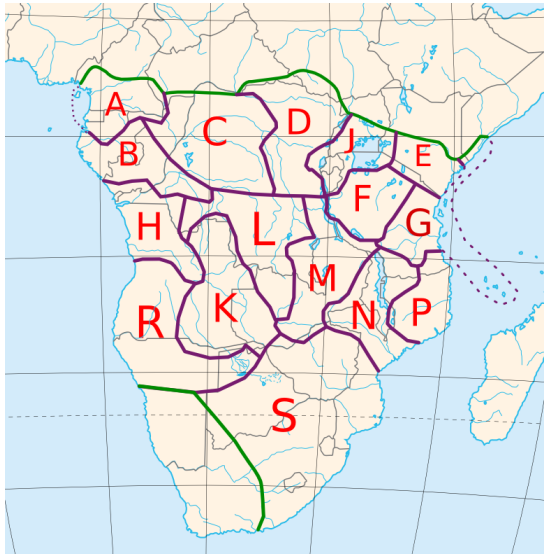
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- 23% or about 11 million people (isiZulu), 8 million (isiXhosa)
- Have very limited ICT support
- They use computers for work, social media... (e.g.: avg. 1.5 mobile connection/pp in SA)
- So, NLP for these languages: searching online, spellcheckers, machine translation, speech, etc.

Basics

- Bantu languages: group of languages spoken in Sub-Saharan Africa
- *Bantu* means 'human'; bit of a laden term, but still used in linguistics
- Number of languages varies by who counts (> 200 at least)
- Organised in so-called Guthrie zones

Guthrie Zones



Core characteristics

- System of noun classes (besides the I, you (sg.), he/she, we, you (pl.), they)
 - For 3rd pers. sg./pl. nouns (i.e., not pers. pron.): they are classified into a noun class
 - Meinhof identified 23 noun classes (not all of them used)
 - There's some semantics to them: e.g., NC1 for humans, NC9 for animals, NC15 infinitive nouns

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 - i.e., what are separate words in, say, English are 'components' of a word
- Ex: titukakimureeterahoganu (Runyankore, Uganda)
'We have never ever brought it to him'

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- neg-(NC2 SC)-RM-(NC7 SC)-(NC1 SC)-VR-App-FV-Loc-Emp-Dec

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neg-(NC2 SC)-RM-(NC7 SC)-(NC1 SC)-VR-App-FV-Loc-Emp-Dec
- System of concordial agreement (more about that soon)

NC	AU	PRE	Stem (example)	Meaning	Example	
1	u-	m(u)-	-fana	humans and other	umfana	boy
2	a-	ba-	-fana	animates	abafana	boys
1a	u-	-	-baba	kinship terms and proper	ubaba	father
2a	o-	-	-baba	names	obaba	fathers
3a	u-	-	-shizi	nonhuman	ushizi	cheese
(2a)	o-	-	-shizi		oshizi	cheeses
3	u-	m(u)-	-fula	trees, plants, non-paired	umfula	river
4	i-	mi-	-fula	body parts	imifula	rivers
5	i-	(li)-	-gama	fruits, paired body parts,	igama	name
6	a-	ma-	-gama	and natural phenomena	amagama	names
7	i-	si-	-hlalo	inanimates and manner/	isihlalo	chair
8	i-	zi-	-hlalo	style	izihlalo	chairs
9a	i-	-	-rabha	nonhuman	irabha	rubber
(6)	a-	ma-	-rabha		amarabha	rubbers
9	i(n)-	-	-ja	animals	inja	dog
10	i-	zi(n)-	-ja		izinja	dogs
11	u-	(lu)-	-thi	inanimates and long thin	uthi	stick
(10)	i-	zi(n)-	-thi	objects	izinthi	sticks
14	u-	bu-	-hle	abstract nouns	ubuhle	beauty
15	u-	ku-	-cula	infinitives	ukucula	to sing
17		ku-		locatives, remote/ general		locative

Concordial agreement—example (isiZulu, South Africa)

Abafana abancane bazozithenga izincwadi ezinkulu

aba-fana **aba**-ncane **ba**- zo- **zi**- thenga **izi**-ncwadi e-**zi**-nkulu
 2.boy 2.small 2.SUBJ-FUT-10.OBJ-buy 10.book REL-10.big

‘The little boys will buy the big books’

Other illustrative examples (isiZulu)

- 'and', enumerative: *na-*, phonologically conditioned

Ex: milk and butter: *ubisi nebhotela*

(-a+i=-e-)

Ex: butter and milk: *ibhotela nobisi*

(-a+u=-o-)

Other illustrative examples (isiZulu)

- 'and', enumerative: *na-*, phonologically conditioned

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- 'is not a': combine NEG SC with PRON, both depend on noun class

Ex: an animal is not a plant: *isilwane asiwona umuthi*

Ex: a plant is not an animal: *umuthi awusona isilwane*

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- 'and', enumerative: *na-*, phonologically conditioned
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 Ex: an animal is not a plant: *isilwane asiwona umuthi*
 Ex: a plant is not an animal: *umuthi awusona isilwane*
- 'all'/'each' ($\forall$), 'at least one' ($\exists$): quantifiers depend on noun class
 Ex: all animals zonke *izilwane* / all plants yonke *imithi*
 Ex: at least one animal: *isilwane esisodwa* / at least one plant *umuthi owodwa*
- copulative (to be): depends on first letter of noun: *ng-* for a-, o-, u-, else y-
 Ex: is a dog: *yinja*
 Ex: is a grandmother: *ngugogo*

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General issues and aims

- Very limited available spellcheckers for use:
 - Outdated/software not working anymore (OpenOffice plugin)
 - Online one with too many clicks, popups, and ads¹

¹https://www.spellchecker.net/africa_zulu_spell_checker.html

General issues and aims

- Very limited available spellcheckers for use:
 - Outdated/software not working anymore (OpenOffice plugin)
 - Online one with too many clicks, popups, and ads¹
- Investigate development of spellchecker for isiZulu
- Find an approach that can be used across (agglutinating) Bantu languages

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What will work best?

- Dictionary approach won't work due to (theoretically) agglutination and (practically) limited online dictionaries

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- Data-driven statistical model or grammar-based (morphological analyser-based) approach?
 - Try that for both isiZulu and isiXhosa

What will work best?

- Dictionary approach won't work due to (theoretically) agglutination and (practically) limited online dictionaries
 - Data-driven statistical model or grammar-based (morphological analyser-based) approach?
 - Try that for both isiZulu and isiXhosa
- ⇒ Rules for the POS categories coded perform better overall (isiXhosa), but data-driven approach faster and more reusable across languages (isiZulu, isiXhosa), despite being underresourced

First iteration [Ndaba et al.(2016)]

1. Use corpus for data
2. Generate n-gram statistics; tried trigrams and quadrigrams; e.g.:
 - original word *ngimbona*
 - trigrams: *ngi*, *gim*, *imb*, ...
 - quadrigrams: *ngim*, *gimb*, ...
3. Compute frequencies of the tri/quadrigrams
4. Determine threshold of when a tri/quadrigram would probably be wrong
5. Then when a word is given:
 - a. Generate its trigrams
 - b. Check probability each trigram
 - c. If tri/quadrigram below threshold: flag word as incorrectly spelled

Example language model creation

corpus	generate trigrams	unique trigrams	frequency	probability
sivela	siv ive vel ela	ala	1	0.03703704
ngihamba	ngi gih iha ham amb mba	amb	1	0.03703704
uvelaphi	uve vel ela lap aph phi	aph	2	0.07407407
ngivala	ngi giv iva val ala	ela	3	0.11111111
uvelaphi	uve vel ela lap aph phi	gih	1	0.03703704
		giv	1	0.03703704
		ham	1	0.03703704
		iha	1	0.03703704
		iva	1	0.03703704
		ive	1	0.03703704
		lap	2	0.07407407
		mba	1	0.03703704
		ngi	2	0.07407407
		phi	2	0.07407407
		siv	1	0.03703704
		uve	2	0.07407407
		val	1	0.03703704
		vel	3	0.11111111

Example how this then works in the spellchecker

File Edit Help

Run Save Copy Paste Clear Help isiZulu

ngihamba
 gnihamba
 ngivela
 ngivea

All trigrams are above the threshold, so it is assumed to have been spelled correctly.

At least one trigram is below the threshold (there is no gni trigram in the language model), so it is probably misspelled, and flagged as such.

A word it was not trained on, but all trigrams are above the threshold, so it is assumed to have been spelled correctly.

At least one trigram is below the threshold (no vea), so it is probably misspelled.

It suggests a correction using more probable trigrams.

Ignore once

Ignore all

Add to dictionary

Suggestions

ngivela

Change

Change all

Exit

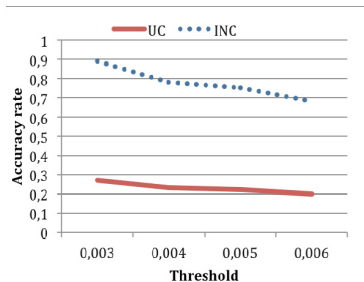
Double click on errors to make correction one at a time

Basic approach for testing

- 10-fold cross-validation for training and testing data set
- 3 corpora to test effect of corpus on accuracy
 - Ukwabelana [Spiegler et al.(2010)]; 288 106 words, 87033 unique
 - Section of the isiZulu National Corpus [Khumalo(2015)]; 538 732 words, 33020 unique
 - IsiZulu news items (collected by MK); 21250 words, 9587 unique
- Different thresholds
- 46 know-to-be-incorrect words added
- Use accuracy as measure, with confusion matrix (TP, TN, FP, FN)

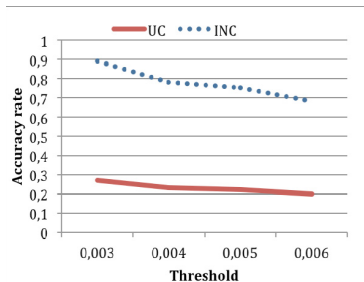
Major outcomes

- 89% accuracy (on par with older data [Bosch and Eisele(2005), Prinsloo and de Schryver(2004)])
- The spellchecker performed slightly better with trigrams than with quadrigrams
- Accurate in detecting words that do not occur in the training corpus
- The most updated corpora are preferable



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- Tests with more data: 83% accuracy with noisy data, 85% with cleaned data

Try this with isiXhosa

- Use code for isiZulu, but feed it isiXhosa texts to create a language model for isiXhosa
- Determine threshold
- Determine accuracy

Try this with isiXhosa: results

- 20K tokens corpus, mainly medical documents
- Threshold: 0.002 (marginally better than 0.003)
- Accuracy: about 79%
- (current implemented version trained with much more text)

Error correction for isiZulu

- Statistical language model based approach as well

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 - e.g., with typo: `nii`
 - intended: `ngi`
 - distance: 1 (a substitution of `i` where there should be `g`)
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 - e.g., with typo: `nii`
 - intended: `ngi`
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- Probabilities of successive trigrams
- Measures:
 - Can it propose something (C_s)?
 - Is the intended word among the proposed words (C_v)? (relevance)

Deletion typo and a suggested correction (running example)

The screenshot shows a spellchecker application window with a menu bar (File, Edit, Help) and a toolbar (Run, Save, Copy, Paste, Clear, Help, isiZulu). The main text area contains the words "ngihamba", "gnihamba", "ngivela", and "ngivea". Annotations explain the spelling analysis for each word:

- ngihamba**: All trigrams are above the threshold, so it is assumed to have been spelled correctly.
- gnihamba**: At least one trigram is below the threshold (there is no gni trigram in the language model), so it is probably misspelled, and flagged as such.
- ngivela**: A word it was not trained on, but all trigrams are above the threshold, so it is assumed to have been spelled correctly.
- ngivea**: At least one trigram is below the threshold (no vea), so it is probably misspelled. It suggests a correction using more probable trigrams.

On the right side, there is a large blue 'A' with a green checkmark. Below it are buttons: "Ignore once", "Ignore all", and "Add to dictionary". A "Suggestions" section shows "ngivela" as a suggestion. At the bottom right are buttons: "Change", "Change all", and "Exit".

Double click on errors to make correction one at a time

Error correction–transposition typo (isiZulu)

yebo, **ngivela** eThekwini

Ignore once

Ignore all

Add to dictionary

Suggestions

ngivela

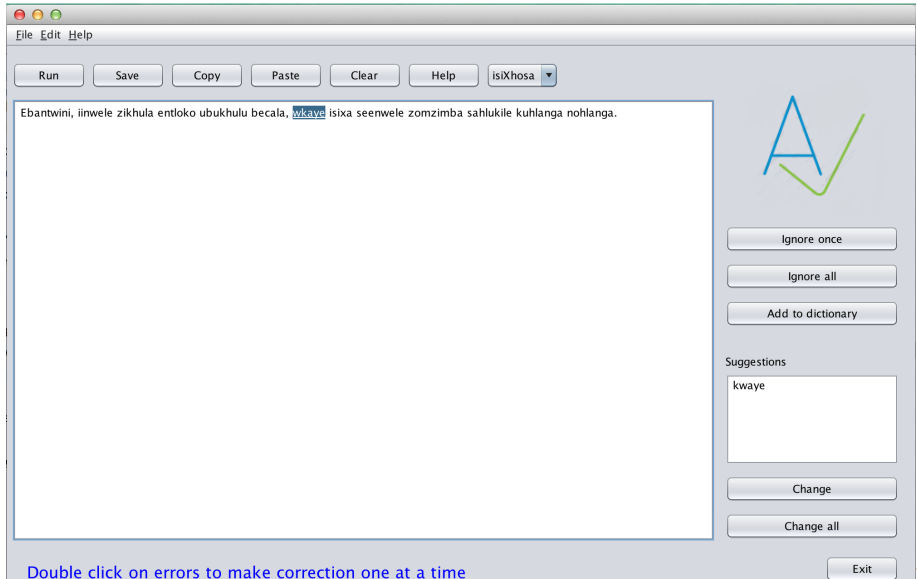
Change

Change all

Exit

Double click on errors to make correction one at a time

Error correction–transposition typo (isiXhosa)



Double click on errors to make correction one at a time

Results

- It can propose something quite well for each type of typo ($> 90\%$ accuracy)
- The relevance varies a lot:
 - Substitutions 59%
 - Insertions 30%
 - Deletions 73%
 - Transpositions 89%

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- The relevance varies a lot:
 - Substitutions 59%
 - Insertions 30%
 - Deletions 73%
 - Transpositions 89%
- Why? We don't know for sure yet

Spelling correction for isiXhosa

- Used the same code as for isiZulu
- But with the isiXhosa language model
- Implemented, but no idea on effectiveness yet

isiZulu text, isiZulu model

File Edit Help

Run Save Copy Paste Clear Help isiZulu ▼

KUBATSHAZWA isihluku owesifazane oneminyaka engu-22 edlwengulwa amadoda ayisihlanu eshintoshana ngaye eNseleni eMpangeni. Umphakathi wakule ndawo usababaza isigameko okuthiwa senzeke ngoLwesibili ebusuku. Kuthiwa owesifazane ubanjwe amadoda athe ayamphelezela esegoduka esuka ejoyintini. Ngokuthola kweSolezwe lo wesifazane kade "ezjabulisa" ejoyintini okuthiwa yiFikile khona eNseleni. Kuthiwa ubecele umfowabo ukuba amhlangabeze. Amadoda amahlanu okuthiwa amenzakalisile kuvela ukuthi aye kuye amtshela ukuthi ayamazi umfowabo ngakho azomphelezela ngoba ubengakafiki. Lo wesifazane kuthiwa uhambe nabasolwa okuthe besendleleni bamjikela. Kuthiwa bahambe naye ngenkani bayomfaka endlini abafike bamdlwengula kuyona. Ekuseni kuthiwa uphunyukile wayobika ngokumehlele. Okhulumela amaphoyisa KwaZulu-Natal uColonel Jay Naicker ukuqinisekile ukuthi amaphoyisa aseMpangeni aphenya icala lokudlwengulwa kowesifazane. "Owesifazane oneminyaka engu-22 uvule icala lokuthunjwa nelokudlwengulwa abasolwa abahlanu emuva kokuba bemthembise ukuthi bazomgodukisa, Akekho osaboshiwe, uphenyo lwamaphoyisa lusaqhubeka," kusho uNaicker. Umthombo ongathandanga ukudalulwa uthe lolu daba lukhulunyelwa phansi endaweni njengoba luthathwa njengehlazo. "Simangazwe yisihluku sabasolwa ngokushintoshana ngengane beyidlwengula. Kuyacaca ukuthi izingane zethu kaziphephile," kusho umthombo. Omunye umthombo uthe kuyadumaza ukuthi lokhu kwenzeka ngenyanga yabesifazane u-Agasti okumele engabe imbokodo iyavikelwa. "Kukhulunye kakhulu ngokuvikelwa kwabesifazane selokhu kuqale u-Agasti, Kuyadumaza ukuthi kukhona abesilisa abasahlukumeza abesifazane ngale ndlela," kusho umthombo.

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Ignore all

Add to dictionary

Suggestions

No suggestions

Change

Change all

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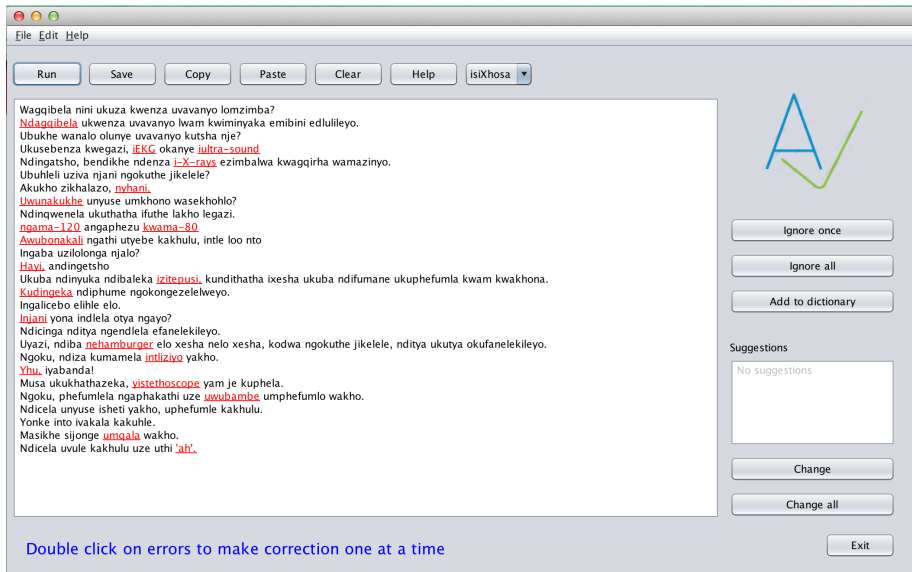
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isiXhosa text, isiXhosa model



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Wagqibela nini ukuza kwenza uvavanyo lomzimba?
Ndagqibela ukwenza uvavanyo lwam kwiminyaka emibini edlulileyo.
 Ubukhe wanalo olunye uvavanyo kutsha nje?
 Ukusebenza kwegazi, iFKG okanye iultra-sound.
 Ndingatsho, bendikhe ndenza i-X-rays ezimbalwa kwagqirha wamazinyo.
 Ubuhleli uziva njani ngokuthe jikelele?
 Akukho zikhalazo, nyhani.
Uwunakukhe unyuse umkhono wasekhohlo?
 Ndingwenela ukuthatha ifuthe lakho legazi.
ngama-120 angaphezu kwama-80.
Awubonakali ngathi utyebe kakhulu, intle loo nto
 Ingaba uzilolonga njalo?
Hayi, andingetsho
 Ukuba ndinyuka ndibaleka izitepusi, kundithatha ixesha ukuba ndifumane ukuphefumla kwam kwakhona.
Kudingeka ndiphume ngokongezelelweyo.
 Ingalicebo elihle elo.
Injani yona indlela otya ngayo?
 Ndinga nditya ngendlela efanelekileyo.
 Uyazi, ndiba nehamburger elo xesha nelo xesha, kodwa ngokuthe jikelele, nditya ukutya okufanelekileyo.
 Ngoku, ndiza kumamela intiliziyo yakho.
Yhu, iyabanda!
 Musa ukukhathazeka, yistethoscope yam je kuphela.
 Ngoku, phefumlela ngaphakathi uze wubambe umphefumlo wakho.
 Ndicela unyuse isheti yakho, uphefumle kakhulu.
 Yonke into ivakala kakuhle.
 Masikhe sijonge umqala wakho.
 Ndicela uvule kakhulu uze uthi 'ah'.

A ✓

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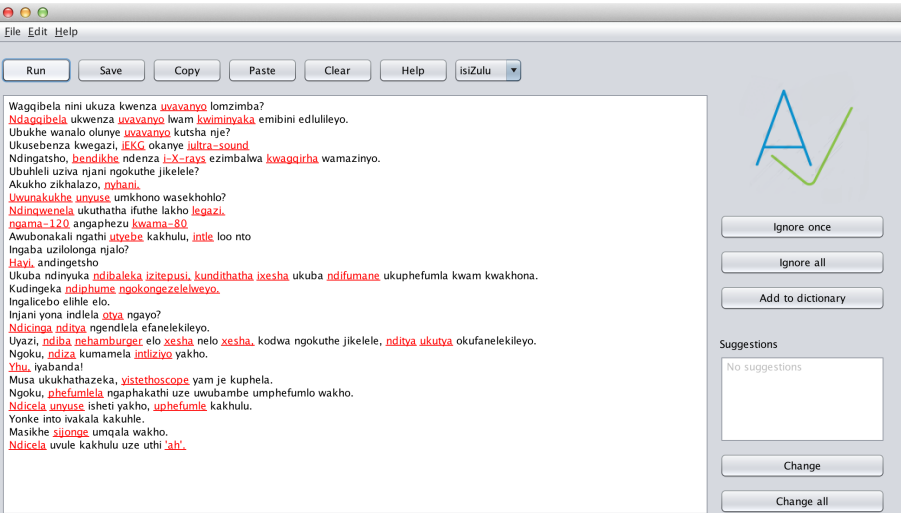
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 Ingaba uzilolonga njalo?
Hayi, andingetsho
 Ukuba ndinyuka ndibaleka izitepusi, kundithatha ixesha ukuba ndifumane ukuphefumla kwam kwakhona.
 Kudingeka ndiphume ngokongezelelweyo.
 Ingalicebo elihle elo.
 Injani yona indlela otya ngayo?
Ndicinga nditya ngendlela efanelekileyo.
 Uyazi, ndiba nehamburger elo xesha nelo xesha, kodwa ngokuthe jikelele, nditya ukutya okufanelekileyo.
 Ngoku, ndiza kumamela intliziyo yakho.
Yhu, iyabanda!
 Musa ukukhathazeka, vistethoscope yam je kuphela.
 Ngoku, phefumlela ngaphakathi uze uwubambe umphefumlo wakho.
Ndicela unyuse isheti yakho, uphefumle kakhulu.
 Yonke into ivakala kakuhle.
 Masikhe sijonge umqala wakho.
Ndicela uvule kakhulu uze uthi 'ah'.

Ignore once

Ignore all

Add to dictionary

Suggestions

No suggestions

Change

Change all

Exit

Double click on errors to make correction one at a time

Discussion

- Setting the threshold is difficult
 - Cleaned data or noisy data?
 - Trigrams on text proper or on non-punctuation-marks?
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- Sociolinguistics, if dialects have words written differently
- Room for improvement on the corrector
- How much do the isiZulu and isiXhosa language models differ?

Outline

- 1 Motivation
 - Context
 - Language 'crash course'
- 2 Corpus-based spellcheckers
 - Error detection for isiZulu and isiXhosa
 - Error correction for isiZulu and isiXhosa
 - Discussion
- 3 Rule-based NLG
 - What is CNL, NLG?
 - Generating basic sentences
 - Language learning exercises
- 4 Summary

Short answer

- **C**ontrolled **N**atural **L**anguage: constrain the grammar/vocabulary of a natural language
- **N**atural **L**anguage **G**eneration: generate natural language text from structured data, information, or knowledge

Natural language interfaces with some CNL or NLG

- Many tools, webpages, etc. with some natural language component
- Querying of information in natural language (cf. a query language SQL, SPARQL)
- Business rules typically specified in a natural language
- etc.

Example: iCal calendar entry with canned text

my colloquium

location None

all-day ☐

from 12/06/2014 01:00 PM
to 12/06/2014 02:00 PM

repeat None ↕

show as Busy ↕

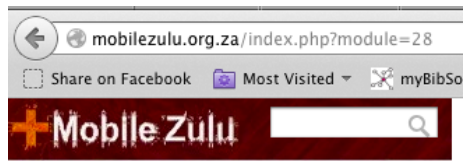
calendar  Work ↕

alarm Message with Sound ↕
 Basso ↕
1 hours before ↕

alarm None ↕

invitees [Add Invitees...](#)

Example: Saadiq Moolla's mobile healthcare app



[Home](#) » [History](#) » [Cardiovascular History](#)

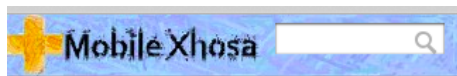
Chest Pain

Have you had any recent pain in your chest? - Uke waba nobuhlungu esifubeni maduzane?

Does the pain radiate to your jaw, neck or arm? - Engabe ubuhlungu bakho bujikeleza emhlathini, emqaleni noma nasezingalweni?

Does anything precipitate or relieve the pain? - Ingabe ikhona into eyenza ubuhlungu buqhubeke noma eyehlisa ubuhlungu?

Dyspnoea



[Home](#) » [History](#) » [Cardiovascular History](#)

Chest Pain

Have you had any recent pain in your chest? - Ingaba kutshanje ukhe weva iintlungu esifubeni?

Does the pain radiate to your jaw, neck or arm? - Ingaba iintlungu zinwenwela emhlathini, entanyeni okanye engalweni?

Does anything precipitate or relieve the pain? - Ingaba ikhon37 / 69

Example: Query formulation with Quelo

[Franconi et al.(2010)]

I am looking for a car dealer. It should sell a new car. The body style of the new car should be an off-road car. The new car should run on a diesel. Its model should be a Range Rover.

I am looking for a car.

Scramble Clear

- it should be equipped with an equipment
 - with an engine
 - with a diesel engine
 - with an electric engine
 - with a gasoline engine
 - with a natural gas engine
 - with a propane engine
 - with an optional feature
 - with a transmission system
- it should be located in a country
- it should be produced by something
- it should be sold by a car dealer
- it should produce something

I am looking for a car. It should run on a diesel.

Scramble Clear Exe

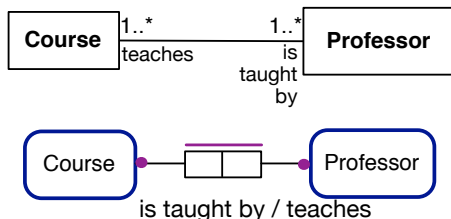
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Ready.

Pictures from: Quelo @ The IESD Challenge 2012

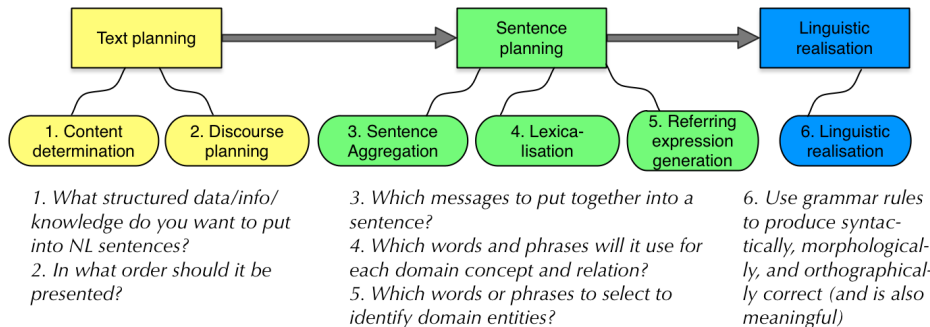
Demo at: <http://krdbapp.inf.unibz.it:8080/quelo/>

Example: Business rules and conceptual data models



Each Course is taught by at least one Professor
Each Professor teaches at least one Course

The 'NLG pipeline'



NLG, principal approaches to generate the text

- Canned text
- Templates
 - Notably for English [Fuchs et al.(2010), Schwitter et al.(2008), Third et al.(2011), Curland and Halpin(2007)],
 - but also other languages [Jarrar et al.(2006)]
- Grammar engines, such as [Kuhn(2013)], Grammatical Framework (<http://www.grammaticalframework.org/>), SimpleNLG

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⇒ CNL, NLG

Business rules/conceptual data models and logic reconstruction

BR: **Each** Course is taught by **at least one** Professor

FOL: $\forall x (\text{Course}(x) \rightarrow \exists y (\text{is_taught_by}(x, y) \wedge \text{Professor}(y)))$

DL: $\text{Course} \sqsubseteq \exists \text{is_taught_by}.\text{Professor}$

Example of templates

<pre><Constraint xsi:type="Mandatory"> <Text> -[Mandatory] Cada</Text> <Object index="0"/> <Text>debe</Text> <Role index="0"/> <Text>al menos un(a)</Text> <Object index="1"/> </Constraint></pre>	<pre><Constraint xsi:type="Mandatory"> <Text> -[Mandatory] Each</Text> <Object index="0"/> <Text>must</Text> <Role index="0"/> <Text>at least one</Text> <Object index="1"/> </Constraint></pre>
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for a large fragment of ORM, and 11 languages [Jarrar et al.(2006)]

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NL Grammars, illustration

Sentence $\longrightarrow$ *NounPhrase* | *VerbPhrase*
NounPhrase $\longrightarrow$ *Adjective* | *NounPhrase*
NounPhrase $\longrightarrow$ *Noun*
...

Noun $\longrightarrow$ *car* | *train*
Adjective $\longrightarrow$ *big* | *broken*
...

(and complexity of the grammar)

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- Can the template-based approach be used also for isiZulu?
 - If so, create those templates
 - If not, start with basics for a grammar engine
- Use a practically useful language to benefit both ICT and linguists and, possibly, some subject domain (e.g., medicine)
- Details in [Keet and Khumalo(2014b), Keet and Khumalo(2014a), Keet and Khumalo(2017)]

A logic foundation for isiZulu knowledge-to-text

- Roughly OWL 2 EL
- OWL 2 EL is a W3C-standardised profile of OWL 2
- Tools, ontologies in OWL 2 (notably SNOMED CT)

ALC syntax

- *Concepts* denoting entity types/classes/unary predicates/universals, including top $\top$ and bottom $\perp$;
- *Roles* denoting relationships/associations/n-ary predicates/properties;
- *Constructors*: and $\sqcap$, or $\sqcup$, and not $\neg$; quantifications for all $\forall$ and exists $\exists$
- *Complex concepts* using constructors: Let C and D be concept names, R a role name, then
 - $\neg C$, $C \sqcap D$, and $C \sqcup D$ are concepts, and
 - $\forall R.C$ and $\exists R.C$ are concepts
- *Individuals*

$\mathcal{ALC}$ semantics

- *domain of interpretation*, and an *interpretation*, where:
 - Domain Δ is a non-empty set of objects
 - Interpretation: $\cdot^{\mathcal{I}}$ is the *interpretation function*, domain $\Delta^{\mathcal{I}}$
 - $\cdot^{\mathcal{I}}$ maps every concept name A to a subset $A^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
 - $\cdot^{\mathcal{I}}$ maps every role name R to a subset $R^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}$
 - $\cdot^{\mathcal{I}}$ maps every individual name a to elements of $\Delta^{\mathcal{I}}$: $a^{\mathcal{I}} \in \Delta^{\mathcal{I}}$
 - Note: $\top^{\mathcal{I}} = \Delta^{\mathcal{I}}$ and $\perp^{\mathcal{I}} = \emptyset$
- $(\neg C)^{\mathcal{I}} = \Delta^{\mathcal{I}} \setminus C^{\mathcal{I}}$
- $(C \sqcap D)^{\mathcal{I}} = C^{\mathcal{I}} \cap D^{\mathcal{I}}$
- $(C \sqcup D)^{\mathcal{I}} = C^{\mathcal{I}} \cup D^{\mathcal{I}}$
- $(\forall R.C)^{\mathcal{I}} = \{x \mid \forall y. R^{\mathcal{I}}(x, y) \rightarrow C^{\mathcal{I}}(y)\}$
- $(\exists R.C)^{\mathcal{I}} = \{x \mid \exists y. R^{\mathcal{I}}(x, y) \wedge C^{\mathcal{I}}(y)\}$

Universal Quantification

- Consider here only the universal quantification at the start of the concept inclusion axiom ('nominal head')
- 'all'/'each' uses *-onke*, prefixed with the oral prefix of the noun class of that first noun (OWL class/DL concept) on lhs of $\sqsubseteq$

(U1) Boy $\sqsubseteq$...

wonke umfana ...

('each boy...'; *u-* + *-onke*)

bonke abafana ...

('all boys...'; *ba-* + *-onke*)

(U2) Phone $\sqsubseteq$...

lonke ifoni ...

('each phone...'; *li-* + *-onke*)

onke amafoni ...

('all phones...'; *a-* + *-onke*)

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	QC _{oral} + onke	QC _{nke}					
1	u-onke → wonke	wo-	aka-	yena	o-	ye-	mu-
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Subsumption

- Two different ways of carving up the nouns to determine which rules apply: semantic and syntactic
- Need to choose between
 - singular and plural
 - with or without the universal quantification voiced
 - generic or determinate

(S1) MedicinalHerb $\sqsubseteq$ Plant

ikhambi ngumuthi

('medicinal herb is a plant')

amakhambi yimithi

('medicinal herbs are plants')

wonke amakhambi ngumuthi

('all medicinal herbs are a plant')

(S2) Giraffes $\sqsubseteq$ Animals

izindlulamithi yizilwane

('giraffes are animals'; generic)

(S3) Cellphone $\sqsubseteq$ Phone

Umakhalekhukhwini uyifoni

('cellphone is a phone'; determ.)

Possible subsumption patterns

- a. N_1 <copulative *ng/y* depending on first letter of N_2 > N_2 .
- b. <plural of N_1 > <copulative *ng/y* depending on first letter of plural of N_2 > <plural of N_2 >.
- c. <All-concord for NC_x >onke <plural of N_1 , being of NC_x > <copulative *ng/y* depending on first letter of N_2 > N_2 .

Subsumption: adding negation

- Need to choose between
 - singular and plural, and with or without the universal quantification voiced
- Copulative is omitted
- Combines the negative subject concord (NEG SC) of the noun class of the first noun (*aku-*) with the pronomial (PRON) of the noun class of second noun (*-yona*)

(SN1) Cup $\sqsubseteq$ $\neg$ Glass

indebe akuyona ingilazi

('cup not a glass')

zonke izindebe aziyona ingilazi

('all cups not a glass')

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1a	u-onke → wonke	wo-	aka-	yena	o-	ye-	mu-
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3a	u-onke → wonke	wo-	aka-	wona	o-	ye-	mu-
(2a)	ba-onke → bonke	bo-	aba-	bona	aba-	bo-	ba-
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Possible negation (disjointness) patterns

- a. $\langle N_1 \text{ of } NC_x \rangle \langle \text{NEG SC of } NC_x \rangle \langle \text{PRON of } NC_y \rangle \langle N_2 \text{ of } NC_y \rangle$.
- b. $\langle \text{All-concord for } NC_x \rangle \text{onke} \langle \text{plural } N_1, \text{ being of } NC_x \rangle \langle \text{NEG SC of } NC_x \rangle \langle \text{PRON of } NC_y \rangle \langle N_2 \text{ with } NC_y \rangle$.

Existential Quantification

(E1) Giraffe $\sqsubseteq \exists$ eats.Twig

yonke indlulamithi idla ihlamvana elilodwa

('each giraffe eats at least one twig')

zonke izindlulamithi zidla ihlamvana elilodwa

('all giraffes eat at least one twig')

- a. <All-concord for NC_x >onke <pl. N_1 , is in NC_x > <conjugated verb>
 < N_2 of NC_y > <RC for NC_y ><QC for NC_y >dwa.

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1a	u-onke → wonke	wo-	aka-	yena	o-	ye-	mu-
2a	ba-onke → bonke	bo-	aba-	bona	aba-	bo-	ba-
3a	u-onke → wonke	wo-	aka-	wona	o-	ye-	mu-
(2a)	ba-onke → bonke	bo-	aba-	bona	aba-	bo-	ba-
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Example

- $\forall x (\text{Professor}(x) \rightarrow \exists y (\text{teaches}(x, y) \wedge \text{Course}(y)))$
- $\text{Professor} \sqsubseteq \exists \text{ teaches. Course}$
- **Each** Professor teaches **at least one** Course

Example

- $\forall x (u\text{Solwazi}(x) \rightarrow \exists y (u\text{fundisa}(x, y) \wedge \text{Isifundo}(y)))$
- $u\text{Solwazi} \sqsubseteq \exists u\text{fundisa}.\text{Isifundo}$
- ?

$\forall x (\text{uSolwazi}(x) \rightarrow \exists y (\text{ufundisa}(x, y) \wedge \text{Isifundo}(y)))$

$\text{uSolwazi} \sqsubseteq \exists \text{ufundisa}.\text{Isifundo}$

$\forall x (\text{uSolwazi}(x) \rightarrow \text{NC} \text{ AU PRE } x, \text{u} \wedge \text{Isifundo}(\text{u}))$

$\text{uSolwazi} \sqsubseteq \exists \text{ufundo}$

look-up NC → 1a

pluralise → 2a

for-all →

NC	AU	PRE
1	u-	m(u)-
2	a-	ba-
1a	u-	-
2a	o-	-
3a	u-	-
(2a)	o-	-
3	u-	m(u)-
4	i-	mi-
5	i-	(li)-
6	a-	ma-
7	i-	si-
8	i-	zi-
9a	i-	-
(6)	a-	ma-
9	i(n)-	-
10	i-	zi(n)-
11	u-	(lu)-
(10)	i-	zi(n)-
14	u-	bu-
15	u-	ku-
17		ku-

Bonke oSolwazi

NC	QC (all)
	QC _{oral} +onke
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$$\forall x (\text{uSolwazi}(x) \rightarrow \exists y (\text{ufundisa}(x, y) \wedge \text{Isifundo}(y)))$$

$\text{uSolwazi} \sqsubseteq \exists (\text{ufundisa})$! ... for relevant NC. Here:

AlgoConjugate

ngi-
u-
u-
si-
ni-
ba-



Bonke oSolwazi bafundisa

$$\forall x (\text{uSolwazi}(x) \rightarrow \exists y (\text{ufundisa}(x, y) \wedge \text{Isifundo}(y)))$$

$$\text{uSolwazi} \sqsubseteq \exists \text{ufundisa} \text{Isifundo}$$


Bonke oSolwazi bafundisa Isifundo

$$\forall x (u\text{Solwazi}(x) \rightarrow \exists y (\text{NC} \text{ AU} \text{ PRE}) \wedge \text{RC} \text{ QC}_{\text{dwa}}))$$

uSolwazi $\nexists$ $\exists$ ufundisa.!

look-up NC

get RC

get QC

add -dwa

	NC	AU	PRE	RC	QC _{dwa}
1	u-	m(u)-			
2	a-	ba-		o-	ye-
1a	u-	-		aba-	bo-
2a	o-	-		o-	ye-
3a	u-	-		aba-	bo-
(2a)	o-	-		o-	ye-
3	u-	m(u)-		aba-	bo-
4	i-	mi-		o-	wo-
5	i-	(li)-		e-	yo-
6	a-	ma-		eli-	lo-
7	i-	si-		a-	wo-
8	i-	zi-		esi-	so-
9a	i-	-		ezi	zo-
(6)	a-	ma-		e-	yo-
9	i(n)-	-		a-	wo-
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11	u-	(lu)-		ezi-	zo-
(10)	i-	zi(n)-		olu-	lo-
14	u-	bu-		ezi-	zo-
15	u-	ku-		obu-	bo-
17		ku-		oku-	zo-

Bonke oSolwazi bafundisa Isifundo esisodwa

How to evaluate?

- Typical way of evaluating: ask linguists and/or intended target group
- Questions depend on what you want to know; e.g.,
 - Does the text capture the semantics adequately?
 - Must it really be grammatically correct or is understandable also acceptable?
 - Compared against alternate representation (figures, tables) or human-authored text?

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- Questions depend on what you want to know; e.g.,
 - Does the text capture the semantics adequately?
 - Must it really be grammatically correct or is understandable also acceptable?
 - Compared against alternate representation (figures, tables) or human-authored text?
- Survey, asked linguists and non-linguists for their preferences
- 10 questions pitting the patterns against each other
- Online, with isiZulu-localised version of Limesurvey

The NLG algorithms can be used elsewhere

- Paper-based language learning exercises
- Exercise books have a lot of exercises on 'give plural noun', 'complete verb' etc

The NLG algorithms can be used elsewhere

- Paper-based language learning exercises
- Exercise books have a lot of exercises on 'give plural noun', 'complete verb' etc
- Our algorithms already can do that!
- Reuse the algorithms to pluralise and conjugate
- Proof of concept tool, tried to use both NLP (corpus, POS tagger) and the grammar engine of NLG

Examples of the CNL it uses

- Pluralise subject

Q: * *Umfowethu bayaphuza*

A: *Abafowethu bayaphuza*

[prefixSG+stem] [PLSC+VerbRoot+FV]

[prefixPL+stem] [PLSC+VerbRoot+FV]

Examples of the CNL it uses

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- Negate the verb

Q: *Batotoba*

A: *Abatotobi*

[PLSC+VerbRoot+FV]

[PLNEGSC+VerbRoot+NEGFV]

Examples of the CNL it uses

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- Possible to combine components for new exercises

[prefixSG+stem] [SGSC+VerbRoot+FV] [prefixSG+stem]

[prefixPL+stem] [PLNEGSC+VerbRoot+NEGFV] [prefixPL+stem]

Q: *umfowethu usula inkomishi* '(my) brother washes the cup'

A: *abafowethu abasuli izinkomishi* '(my) brothers do not wash the cups'

Outline

- 1 Motivation
 - Context
 - Language ‘crash course’
- 2 Corpus-based spellcheckers
 - Error detection for isiZulu and isiXhosa
 - Error correction for isiZulu and isiXhosa
 - Discussion
- 3 Rule-based NLG
 - What is CNL, NLG?
 - Generating basic sentences
 - Language learning exercises
- 4 Summary

Summary

- Some natural language understanding, some generation
- N-grams and learning from a corpus (spellchecker)
- Corpus affects how well the tool performs (spellchecker, isiZulu CALL)
- Templates inapplicable to isiZulu due to its grammar (OWL verbalisation), hence a tailor-made grammar engine
- NLG algorithms generic and modularised in the sense that they can be reused in other tools (CALL exercises)
- Not addressed much now, but no less important: underresourced language

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Thank you!

Questions?

Spellchecker with contributions from:

- IsiZulu Linguist: Langa Khumalo
- IsiZulu spellchecker
 - Hussein Suleman, Balone Ndaba, Langa Khumalo, Norman Pilusa, Frida Mjaria
- IsiXhosa spellchecker
 - Nthabiseng Mashiane, Siseko Neti, Norman Pilusa
- Participants in the evaluations from ULPDO@UKZN and Linguistics@UCT
- Additional texts from INC, Mantoa Motinyane-Masoko, MeMaT translators, publicly available texts