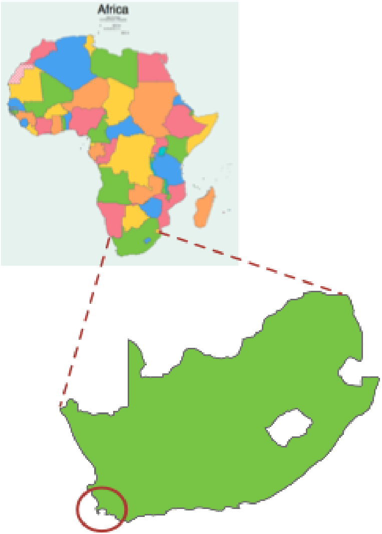
Knowledge-to-text Natural Language Generation for Agglutinating African Languages

C. Maria Keet

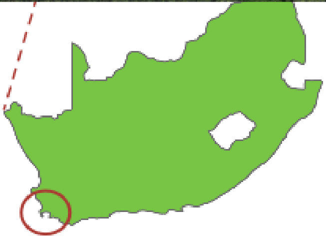
Department of Computer Science
University of Cape Town, South Africa
mkeet@cs.uct.ac.za

Tech Talk at Google, Zurich, Switzerland
Wikimedia Foundation Google.org Fellows offsite workshop, 23-26 August 2022

CS@UCT



CS@UCT



KEEN team

- Knowledge engineering team: `http://www.meteck.org/keen/`
- Aim: to contribute computing theory, methods, and techniques to the knowledge society
- Scope is knowledge engineering in its broad sense, including ontology engineering, the Semantic Web, intelligent (logic-based, ontology-driven) conceptual modelling, and natural language generation

Outline

Outline

1. Motivation
   - Context
   - Notes on NCB languages
2. Rule-based NLG
   - CNL and NLG in a nutshell
   - Generating basic sentences in isiZulu
   - Extending basic sentences
3. Discussion
4. Summary

Outline

Motivation

- >1.4 billion people in Africa, most do or can speak a language other than English or French
  - South Africa: isiZulu and isiXhosa most widely spoken languages, by first language speakers
  - 23% or about 11 million people isiZulu, 8 million (isiXhosa)

Motivation

- >1.4 billion people in Africa, most do or can speak a language other than English or French
  - South Africa: isiZulu and isiXhosa most widely spoken languages, by first language speakers
  - 23% or about 11 million people isiZulu, 8 million (isiXhosa)
- People use computers for work, social media...
  - Doing business, government services provision, etc in one's own language, beyond English and French
  - (The "untapped billion")
- ... but there is very limited ICT in/for African languages of the Niger-Congo family, and only for a few languages

Motivation

- NLP tools also for African languages proper
- Requires tools with African languages in at least the interface, not just some ‘pretty pictures and icons’
- A.o.t., need to transform structured data and structured knowledge into text
- Structured input is represented in, a.o.: XML, RDF, OWL, SQL, JSON, spreadsheets, csv files

Structured input – examples

OWL snippet:


```
-<!--
   http://www.meteck.org/teaching/OEbook/ontologies/AfricanWildlifeOntology1.owl#CarnivorousPlant
 -->
-<owl:Class rdf:about="http://www.meteck.org/teaching/OEbook/ontologies/AfricanWildlifeOntology1.owl#CarnivorousPlant">
   <rdfs:subClassOf rdf:resource="http://www.meteck.org/teaching/OEbook/ontologies/AfricanWildlifeOntology1.owl#plant"/>
  -<rdfs:subClassOf>
    -<owl:Restriction>
       <owl:onProperty rdf:resource="http://www.meteck.org/teaching/OEbook/ontologies/AfricanWildlifeOntology1.owl#eats"/>
       <owl:someValuesFrom rdf:resource="http://www.meteck.org/teaching/OEbook/ontologies/AfricanWildlifeOntology1.owl#animal"/>
     </owl:Restriction>
   </rdfs:subClassOf>
 </owl:Class>
```


JSON:


```
relationshipTypes:
  0:
    name:                "Depencency"
    participants:
      0:
        name:            "Employee"
        role:            "provides_for"
        participation:   "strong"
        min:             "0"
        max:             "N"
      1:
        name:            "Dependent"
        role:            "supported"
        participation:   "weak"
        min:             "1"
        max:             "1"
```


XML:


```
-<CATALOG>
  -<PLANT>
     <COMMON>Bloodroot</COMMON>
     <BOTANICAL>Sanguinaria canadensis</BOTANICAL>
     <ZONE>4</ZONE>
     <LIGHT>Mostly Shady</LIGHT>
     <PRICE>$2.44</PRICE>
     <AVAILABILITY>031599</AVAILABILITY>
   </PLANT>
  -<PLANT>
     <COMMON>Columbine</COMMON>
```

Structured sentences – examples for knowledge-to-text

- Electronic health records and patient discharge notes generation

- Requirements engineering and CQs for app development

- Querying the data with conceptual queries in OBDA

- And many other areas; e.g., question generation, intelligent textbooks, automation of language learning exercises

Structured sentences – examples for knowledge-to-text

- Electronic health records and patient discharge notes generation
    - e.g., SNOMED CT, OpenMRS localisation
    - "The patient has as symptom fever and dizziness"
    - "The patient must drink water when taking the pills"
      "If the patient takes the pills, then he must drink water"
- Requirements engineering and CQs for app development
    - Capture and validate relevant business logic
    - "Who works for the HR Department?"
- Querying the data with conceptual queries in OBDA
    - "Show me all employees who are not working on a project"
- And many other areas; e.g., question generation, intelligent textbooks, automation of language learning exercises

Structured sentences – examples for knowledge-to-text

- Electronic health records and patient discharge notes generation
  - e.g., SNOMED CT, OpenMRS localisation
  - "The patient has as symptom fever **and** dizziness"
  - "The patient must drink water **when** taking the pills"
    "**If** the patient takes the pills, **then** he must drink water"
- Requirements engineering and CQs for app development
  - Capture and validate relevant business logic
  - "**Who** works for the HR Department?"
- Querying the data with conceptual queries in OBDA
  - "Show me **all** employees who are **not** working on a project"
- And many other areas; e.g., question generation, intelligent textbooks, automation of language learning exercises

This talk

- Rule-based Controlled Natural Languages & Natural Language Generation
- Knowledge-to-text; input: ontologies, knowledge graphs etc
- Agglutinating Niger-Congo B languages (aka ‘bantu languages’)

Outline

1. Motivation
   - Context
   - Notes on NCB languages
2. Rule-based NLG
   - CNL and NLG in a nutshell
   - Generating basic sentences in isiZulu
   - Extending basic sentences
3. Discussion
4. Summary

Basics

1500-2000 African languages (6 main groups) spoken by 1.4 billion people

https://en.wikipedia.org/wiki/Bantu_languages#/media/File:African_language_families.png

Core characteristics relevant for computation (1/2)

1. System of noun classes
   - Each noun is classified into a noun class
   - Meinhof identified 23 noun classes; not all of them used, varies by language; some refinements
   - Singular and plural pairings (with imprecision and underspecification)
   - There's semantics to the NCs (e.g., NC1 for humans, NC9 for animals, NC15 infinitive nouns); less important for computation

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

Core characteristics relevant for computation (2/2)

2. Many of the languages are *agglutinating*
   - 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'
`ti tu ka ki mu reet er a ho ga nu`
neg-(NC2 SC)-RM-(NC7 OC)-(NC1 OC)-VR-App-FV-Loc-Emp-Dec

Illustrative examples of some consequences (isiZulu)

- ‘and’, enumerative: *na-*, phonologically conditioned

  Ex: milk and butter: *ubisi <u>ne</u>bhotela* (-a+i-=-e-)

  Ex: butter and milk: *ibhotela <u>no</u>bisi* (-a+u-=-o-)

Illustrative examples of some consequences (isiZulu)

- 'and', enumerative: *na-*, phonologically conditioned
  - Ex: milk and butter: *ubisi <u>ne</u>bhotela* (-a+i-=-e-)
  - Ex: butter and milk: *ibhotela <u>no</u>bisi* (-a+u-=-o-)
- Verbs: concordial agreement ($\sim$ conjugation) based on noun class
  - Ex: The human eats *umuntu <u>u</u>dla*
  - Ex: The dog eats *inja <u>i</u>dla*

Illustrative examples of some consequences (isiZulu)

- ‘and’, enumerative: *na-*, phonologically conditioned
  - Ex: milk and butter: *ubisi <u>ne</u>bhotela* (-a+i-=-e-)
  - Ex: butter and milk: *ibhotela <u>no</u>bisi* (-a+u-=-o-)
- Verbs: concordial agreement (∼ conjugation) based on noun class
  - Ex: The human eats *umuntu <u>u</u>dla*
  - Ex: The dog eats *inja <u>i</u>dla*
- ‘is not a’: combine NEG SC with PRON, both depend on nc
  - Ex: an animal is not a plant: *isilwane <u>asiwona</u> umuthi*
  - Ex: a plant is not an animal: *umuthi <u>awusona</u> isilwane*

Concordial agreement

3. System of concordial agreement

Abafana abancane bazozithenga izincwadi ezinkulu (isiZulu, South Africa)

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'

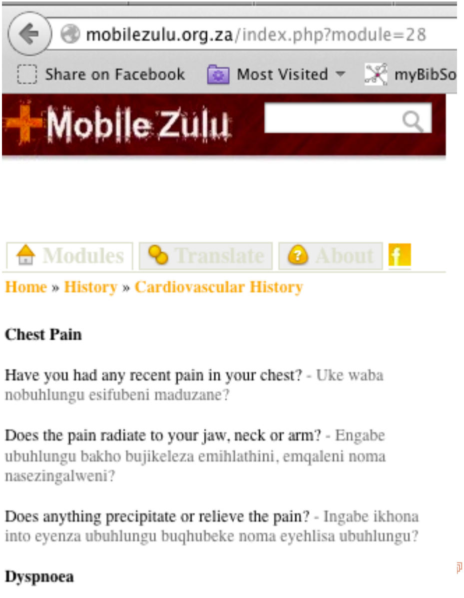
Outline

Outline

Short answer

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

Ex: S. Moolla's mobile healthcare app with **canned text**



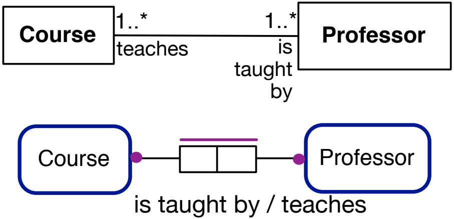
Ex: Avalanche bulletins with **canned segments** [Winkler et al.(2014)]

Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
die Lawinen	können			gross werden.
nasse Lawinen		auch	oft	weit vorstossen.
diese		{on_steep} Sonnenhängen	weiterhin	bis in die aperen Täler vorstossen.
		in diesen Gebieten		bis in tiefe Lagen vorstossen.

Segment 3a	Segment 1	Segment 2	Segment 3b	Segment 4	Segment 5
	the avalanches	can			reach large size.
	wet avalanches		also	in many cases	reach a long way.
{on_steep} sunny slopes	they			as before	reach the bare valleys.
in these regions					reach low altitudes.

Fig. 2. Schema of a phrase in the source language German (above). {on_steep} mark a sub-segment with several further options. In this example, [blank] is one of the options in the third and fourth segment. In English, the order of the segments is different and segment 3 is split.

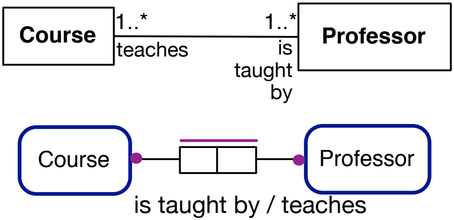
Ex: Business rules and conceptual data models with *static* **templates**



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

Each `[C1]` `[R1]` **at least one** `[C2]`

With logic-based 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: $\text{Course} \sqsubseteq \exists\ \text{is\_taught\_by}.\text{Professor}$

- mandatory constraint / existential quantification (all-some pattern)
- **Each** [C1] [R1] **at least one** [C2]

ORM model snippet, serialised in XML

```
...
<Predicate>
<Object_Role ID='ExEN:249' Object='Professor' Role='teaches'/>
<Object_Role ID='ExEN:250' Object='Course' Role='taught'/>
</Predicate>
...
<Constraint xsi:type='Mandatory'>
<Object_Role>ExEN:249</Object_Role>
</Constraint>
...
```

Example of static templates in ES and EN

Simple existential quantification ('mandatory constraint') template

Each [C1] [R1] **at least one** [C2]

```
<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>
```

```
<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>
```

for a large fragment of ORM, and 11 languages [Jarrar et al.(2006)]

Example of static templates in ES and EN

Simple existential quantification (‘mandatory constraint’) template

Each [C1] [R1] **at least one** [C2]

```
<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>
```

```
<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>
```

for a large fragment of ORM, and 11 languages [Jarrar et al.(2006)]

Example of static templates in ES and EN

Simple existential quantification (‘mandatory constraint’) template

Each [C1] [R1] **at least one** [C2]

```
<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>
```

```
<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>
```

for a large fragment of ORM, and 11 languages [Jarrar et al.(2006)]

Example of static templates in ES and EN

Simple existential quantification (‘mandatory constraint’) template

Each [C1] [R1] **at least one** [C2]

```
<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>
```

```
<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>
```

for a large fragment of ORM, and 11 languages [Jarrar et al.(2006)]

Mixing grammar with templates

- Idea: store the words in their base form with POS tag, specify in the 'template' what needs to be done with it, use a realisation engine to finalise the sentence
- Same stems or words and core structure of the grammar-infused template, generate different sentences based on grammatical features declared
  - yes/no pronomial, present/past tense, gender

Somewhat fancier templates

```
((template clause)
   (act 'eat')
   (agent ((template noun-phrase)
     (np-type PROPER)
     (head 'John')
     (gender MASCULINE)
     (pronominal NO)))
   (object ((template noun-phrase)
     (head 'apple')
     (pronominal YES))))
```

John eats it

```
((template clause)
   (act 'eat')
   (agent ((template noun-phrase)
     (np-type PROPER)
     (head 'John')
     (gender FEMININE)
     (pronominal YES)))
   (object ((template noun-phrase)
     (head 'apple')
     (pronominal NO))))
```

She eats an apple

NL Grammars, illustration (1/2)

$$
\begin{aligned}
Sentence &\longrightarrow NounPhrase \mid VerbPhrase \\
NounPhrase &\longrightarrow Adjective \mid NounPhrase \\
NounPhrase &\longrightarrow Noun \\
\ldots & \\
\\
Noun &\longrightarrow car \mid train \\
Adjective &\longrightarrow big \mid broken \\
\ldots &
\end{aligned}
$$

+ rules for verb tenses, pluralisation etc.

SimpleNLG tool [Gatt and Reiter(2009)] (2/2)

with grammars for EN, FR, ES, PT, NL, DE, and Galician

```
<Document>
  <child xsi:type="SPhraseSpec">
    <subj xsi:type="VPPhraseSpec" FORM="PRESENT_PARTICIPLE">
      <head cat="VERB">
        <base>refactor</base>
      </head>
    </subj>
    <vp xsi:type="VPPhraseSpec" TENSE="PRESENT" >
      <head cat="VERB">
        <base>be</base>
      </head>
      <compl xsi:type="VPPhraseSpec" FORM="PAST_PARTICIPLE">
        <head cat="VERB">
          <base>need</base>
        </head>
      </compl>
    </vp>
  </child>
</Document>
```

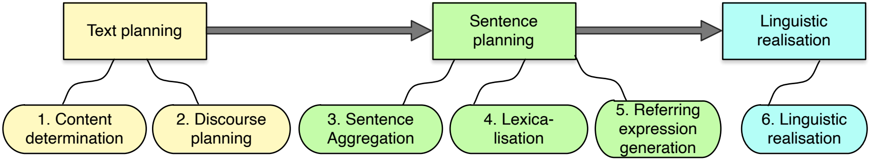
Generates: “Refactoring is needed”

https://github.com/simplenlg/simplenlg

NLG, principal approaches to generate the text

- ~~Canned text, with complete sentences (CNLs only)~~
- Canned segments to make a sentence (CNL mostly, not NLG)
- Templates (different types)
  - Mainly for English but also other languages
  - Hand-crafted ('old' approach) or ML/neural-based ('new')
- Grammar engines
  - e.g., such as [Kuhn(2013)], Grammatical Framework (`http://www.grammaticalframework.org/`), SimpleNLG [Gatt and Reiter(2009)]
- Different ways to mix 'simple' static templates with grammar rules [Mahlaza and Keet(2020)]

The ‘NLG pipeline’



1. What structured data/info/ knowledge do you want to put into NL sentences?
2. In what order should it be presented?

3. Which messages to put together into a sentence?
4. Which words and phrases will it use for each domain concept and relation?
5. Which words or phrases to select to identify domain entities?

6. Use grammar rules to produce syntac-tically, morphological-ly, and orthographical-ly correct (and is also meaningful)

(based on [Reiter and Dale(1997)])

Outline

Question

- Can we use any of the simple template-based approaches for agglutinating Niger-Congo B languages?

Question

- Can we use any of the simple template-based approaches for agglutinating Niger-Congo B languages?
  - It depends... but mostly: no

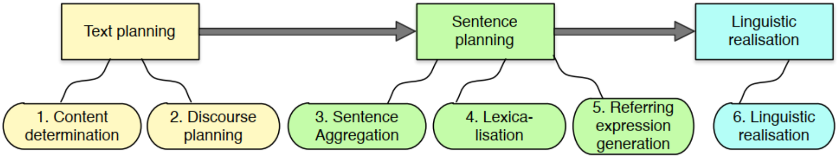
Question

- Can we use any of the simple template-based approaches for agglutinating Niger-Congo B languages?
  - It depends... but mostly: no
- Tasks:
  - For structured input: use a practically useful language with tool support already (Semantic Web technologies)
  - Start with basics for a grammar engine (develop the new algorithms)
  - Pick an appealing sample domain (e.g., health)
  - Do it in a way so as to benefit both ICT and linguists

Question

- Can we use any of the simple template-based approaches for agglutinating Niger-Congo B languages?
  - It depends... but mostly: no
- Tasks:
  - For structured input: use a practically useful language with tool support already (Semantic Web technologies)
  - Start with basics for a grammar engine (develop the new algorithms)
  - Pick an appealing sample domain (e.g., health)
  - Do it in a way so as to benefit both ICT and linguists
- First language to experiment with: isiZulu [Keet and Khumalo(2014b), Keet and Khumalo(2014a), Keet and Khumalo(2017a)]

Ontology verbalisation



1. What structured data/info/ knowledge do you want to put into NL sentences?
2. In what order should it be presented?

3. Which messages to put together into a sentence?
4. Which words and phrases will it use for each domain concept and relation?
5. Which words or phrases to select to identify domain entities?

6. Use grammar rules to produce syntac-tically, morphological-ly, and orthographical-ly correct (and is also meaningful)

The NLG 'pipeline'

Ontology verbalisation

1. The (OWL) ontology
2. Your choice (e.g., first all classes and class expressions in the TBox, then the object properties, etc.)

3. Aim: sentence for each axiom
4. Use vocabulary of the ontology; Select term for each constructor in the language (Each/All, and, some/at least one)
5. Combine related small axiom, or to relate the sentences generated for a large axiom

6. Language-specific issues (e.g., singular/plural of the class in agreement with conjugation of the verb, 'a' and 'an' vs 'a(n)', etc.)

$\mathcal{ALC}$ syntax (a popular description logic)

- Concepts denoting entity types/classes/unary predicates/universals, including top $\top$ and bottom $\bot$;
- Roles denoting relationships/associations/n-ary predicates/properties;
- Constructors: and $\sqcap$, or $\sqcup$, and not $\neg$; quantifiers 'for all' $\forall$ and 'there 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

– e.g., $Lion \sqsubseteq \exists eats.Herbivore \sqcap \forall eats.Herbivore$

$\mathcal{ALC}$ 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 $\bot^{\mathcal{I}} = \emptyset$
- $(\neg C)^{\mathcal{I}} = \Delta^{\mathcal{I}} \backslash C^{\mathcal{I}}$
- $(C \sqcap D)^{\mathcal{I}} = C^{\mathcal{I}} \cap D^{\mathcal{I}}$
- $(C \sqcup D)^{\mathcal{I}} = C^{\mathcal{I}} \cup D^{\mathcal{I}}$
- $(\forall R.C)^{\mathcal{I}} = \{x \mid \forall y.R^{\mathcal{I}}(x,y) \rightarrow C^{\mathcal{I}}(y)\}$
- $(\exists R.C)^{\mathcal{I}} = \{x \mid \exists y.R^{\mathcal{I}}(x,y) \wedge C^{\mathcal{I}}(y)\}$

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` $\sqsubseteq$ ...

<u>wonke</u> umfana ... ('<u>each</u> boy...'; *u-* + *-onke*)

<u>bonke</u> abafana ... ('<u>all</u> boys...'; *ba-* + *-onke*)

(U2) `Phone` $\sqsubseteq$ ...

<u>lonke</u> ifoni ... ('<u>each</u> phone...'; *li-* + *-onke*)

<u>onke</u> amafoni ... ('<u>all</u> phones...'; *a-* + *-onke*)

NC	QC (all)		NEG SC	PRON	RC	QC_{dwa}	EC
	$QC_{oral+onke}$	QC_{nke}					
1	u-onke → wonke	wo-	aka-	yena	o-	ye-	mu-
2	ba-onke → bonke	bo-	aba-	bona	aba-	bo-	ba-
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-
3	u-onke → wonke	wo-	awu-	wona	o-	wo-	mu-
4	i-onke → yonke	yo-	ayi-	yona	e-	yo-	mi-
5	li-onke → lonke	lo-	ali-	lona	eli-	lo-	li-
6	a-onke → onke	o-	awa-	wona	a-	wo-	ma-
7	si-onke → sonke	so-	asi-	sona	esi-	so-	si-
8	zi-onke → zonke	zo-	azi-	zona	ezi	zo-	zi-
9a	i-onke → yonke	yo-	ayi-	yona	e-	yo-	yi-
(6)	a-onke → onke	o-	awa-	wona	a-	wo-	ma-
9	i-onke → yonke	yo-	ayi-	yona	e-	yo-	yi-
10	zi-onke → zonke	zo-	azi-	zona	ezi-	zo-	zi-
11	lu-onke → lonke	lo-	alu-	lona	olu-	lo-	lu-
(10)	zi-onke → zonke	zo-	azi-	zona	ezi-	zo-	zi-
14	ba-onke → bonke	bo-	abu-	bona	obu-	bo-	bu-
15	ku-onke → konke	zo-	aku-	khona	oku-	zo-	ku-

NC	QC (all) QC_{oral}-onke	QC_{nke}	NEG SC	PRON	RC	QC_{dwa}	EC
1	u-onke → wonke	wo-	aka-	yena	o-	ye-	mu-
2	ba-onke → bonke	bo-	aba-	bona	aba-	bo-	ba-
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-
3	u-onke → wonke	wo-	awu-	wona	o-	wo-	mu-
4	i-onke → yonke	yo-	ayi-	yona	e-	yo-	mi-
5	li-onke → lonke	lo-	ali-	lona	eli-	lo-	li-
6	a-onke → onke	o-	awa-	wona	a-	wo-	ma-
7	si-onke → sonke	so-	asi-	sona	esi-	so-	si-
8	zi-onke → zonke	zo-	azi-	zona	ezi	zo-	zi-
9a	i-onke → yonke	yo-	ayi-	yona	e-	yo-	yi-
(6)	a-onke → onke	o-	awa-	wona	a-	wo-	ma-
9	i-onke → yonke	yo-	ayi-	yona	e-	yo-	yi-
10	zi-onke → zonke	zo-	azi-	zona	ezi-	zo-	zi-
11	lu-onke → lonke	lo-	alu-	lona	olu-	lo-	lu-
(10)	zi-onke → zonke	zo-	azi-	zona	ezi-	zo-	zi-
14	ba-onke → bonke	bo-	abu-	bona	obu-	bo-	bu-
15	ku-onke → konke	zo-	aku-	khona	oku-	zo-	ku-

Subsumption (axiom pattern $A \sqsubseteq B$)

- 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) (generic)

(S3) (determinate)

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$.

Existential Quantification (axiom pattern $A \sqsubseteq \exists R.B$)

(E1) Giraffe $\sqsubseteq$ ∃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.

Walk-though of the algorithm

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

Walk-though of the algorithm

- $\forall x\ (\text{uSolwazi}(x) \rightarrow \exists y\ (\text{-fundisa}(x, y) \land \text{Isifundo}(y)))$
- $\text{uSolwazi} \sqsubseteq \exists\ \text{-fundisa}.\text{Isifundo}$
- ?

$$\forall x\ (\text{uSolwazi}(x) \rightarrow \exists y\ (\text{-fundisa}(x, y) \land \text{Isifundo}(y)))$$

$$\text{uSolwazi} \sqsubseteq \exists\ \text{-fundisa}.\text{Isifundo}$$

$\forall x$ (uSolwazi(x) → … (x, …) ∧ …

uSolwazi ⊑ ∃ -func…

look-up NC → 1a

pluralise → 2a

for-all → bonke

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-

NC	QC (all) $QC_{oral+onke}$
1	u-onke → wonke
2	ba-onke → bonke
1a	u-onke → wonke
2a	ba-onke → bonke
3a	u-onke → wonke
(2a)	ba-onke → bonke
3	u-onke → wonke
4	i-onke → yonke
5	li-onke → lonke
6	a-onke → onke
7	si-onke → sonke
8	zi-onke → zonke
9a	i-onke → yonke
(6)	a-onke → onke
9	i-onke → yonke
10	zi-onke → zonke
11	lu-onke → lonke
(10)	zi-onke → zonke
14	ba-onke → bonke
15	ku-onke → konke

↓

Bonke oSolwazi

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

$\text{uSolwazi} \sqsubseteq \exists\,\text{-fundisa}.\text{Isifundo}$

reuse pluralised NC of subject

look-up SC of that NC

NC	SC
1 2	u- ba-
1a 2a	u- ba-
3a 2a	u- ba-
3 4	u- i-
5 6	li- a-
7 8	si- zi-
9a 6	i- a-
9 10	i- zi-
11 10	lu- zi-
14	bu-
15	ku-
17	lu-

Bonke oSolwazi bafundisa

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

$$\text{uSolwazi} \sqsubseteq \exists\ \text{-fundisa}.\text{Isifundo}$$

Bonke oSolwazi bafundisa Isifundo

$\forall x\ (\text{uSolwazi}(x) \rightarrow \exists y$ … $) \wedge$ … $))$

uSolwazi $\sqsubseteq \exists$ fundisa.Is…

look-up NC

get RC

get QC

add -dwa

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-

RC	QC_{dwa}
o-	ye-
aba-	bo-
o-	ye-
aba-	bo-
o-	ye-
aba-	bo-
o-	wo-
e-	yo-
eli-	lo-
a-	wo-
esi-	so-
ezi	zo-
e-	yo-
a-	wo-
e-	yo-
ezi-	zo-
olu-	lo-
ezi-	zo-
obu-	bo-
oku-	zo-

Bonke oSolwazi bafundisa Isifundo esisodwa

English cf. isiZulu for the "all-some" pattern

Axiom type 'all-some' ontology pattern (mandatory constraint)

$\forall x(X(x) \rightarrow \exists y(R(x,y) \wedge Y(y)))$

$X \sqsubseteq \exists R.Y$

English All [noun x pl.] [verb 3rd pers. pl.] at least one [noun y]

All professors teach at least one course

All professors write at least one book

All carnivores eat at least one animal

All elephants eat at least one apple

IsiZulu [QCall$_{nc_{x},pl}$] [noun x$_{nc_x}$ pl.] [SC$_{nc_{x},pl}$-verb] [noun y$_{nc_y}$] RC$_{nc_y}$-QC$_{nc_y}$-dwa

Bonke oSolwazi bafundisa isifundo esisodwa

Bonke oSolwazi babhala incwadi eyodwa

Onke amakhanivo adla isilwane esisodwa

Zonke izindlovu zidla i-apula elilodwa

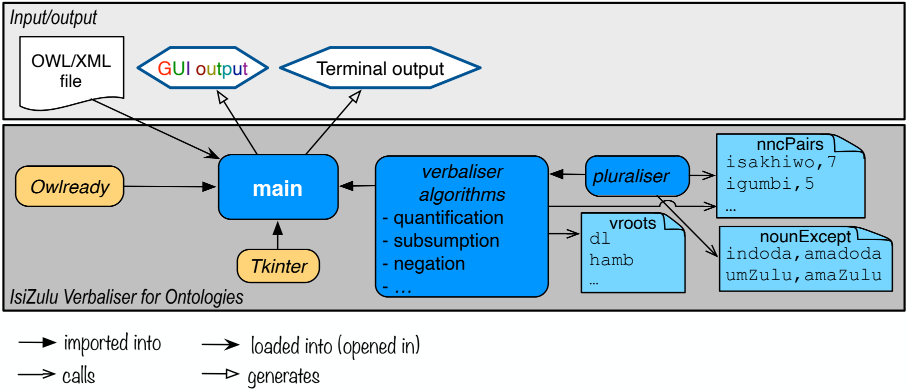
Evaluation

- Typical way of evaluating: ask linguists and/or intended target group
- Survey, asked linguists and non-linguists for their preferences
- 10 questions pitting the patterns against each other
- Online, with isiZulu-localised version of Limesurvey

Evaluation – interesting results

- Linguist agreed more among each other than the ‘non-linguists’
- More agreement for the shorter sentences
- Open questions on ‘deep Zulu’ vs ‘township Zulu’, level of education in isiZulu, dialects
  - Sociolinguistics is not our task to investigate, but it may affect human evaluation results w.r.t. quality, grammaticality, naturalness

Proof-of-concept implementation (1/3)



[Keet et al.(2017)]

Proof-of-concept implementation (2/3)

Algorithm 3 (AllSome) Verbalisation of "all-some" axiom type ($C \sqsubseteq \exists R.D$)

Require: $\mathcal{C}$ set of classes, language $\mathcal{L}$ with $\sqsubseteq$ for subsumption and $\exists$ for existential quantification; variables: A axiom, NC_i noun class, $c_1, c_2 \in \mathcal{C}$, $o \in \mathcal{R}$, a_1 a term; r_2, q_2 concords; functions: $getFirstClass(A)$, $getSecondClass(A)$, $getNC(C)$, $getRC(NC_i)$, $getQC(NC_i)$, $getVSofOP(o)$.

Require: axiom A with a $\sqsubseteq$ has been retrieved **and** an $\exists$ on the rhs of the inclusion

$c_1 \leftarrow getFirstClass(A)$ {get subclass}
$c_2 \leftarrow getSecondClass(A)$ {get superclass}
$o \leftarrow getObjProp(A)$ {get object property}
$v \leftarrow getVSofOP(o)$ {get verb stem of object property}
$NC_1 \leftarrow getNC(c_1)$ {determine noun class by augment and prefix or dictionary}
$NC_2 \leftarrow getNC(c_2)$ {determine noun class by augment and prefix or dictionary}
$NC_1' \leftarrow$ lookup plural nounclass of NC_1 {from known list}
$c_1' \leftarrow pluralise(c_1, NC_1')$ {call algorithm *pluralise* to generate a plural from o}
$a_1 \leftarrow$ lookup quantitative concord for NC_1' {from quantitative concord (QC(all)) list}
$r_2 \leftarrow getRC(NC_2)$ {get relative concord for c_2 from the QC_{dwa}-list}
$q_2 \leftarrow getQC(NC_2)$ {get quantitative concord for c_2 from the QC_{dwa}-list}
if $checkNegation(A) == true$ **then**
    {use *negation* (Algorithm 4)}
else
    if o annotated with present tense **then**
        $conj_{nc1} \leftarrow$ lookup SC of NC_1' {from known SC list}
        $o' \leftarrow conj_{nc1} v$ {generate conjugated verb}
        RESULT $\leftarrow$ 'a_1 c_1' o'a c_2 $r_2 q_2$dwa.' {verbalise the axiom}
    else
        RESULT $\leftarrow$ '*passive voice and inverses are not supported yet.*'
    end if
end if
return RESULT

https://github.com/mkeet/GENIproject/

Proof-of-concept implementation (2/3)

```
#simple existential quantification
# modified cf zulurules to handle also vowel-commencing vroots
def exists_zu(sub,op,super):
    nc1m = find_nc(sub)
    nc2m = find_nc(super)
    pl = plural_zu(sub,nc1m)
    nc2 = strip_m(nc2m)
    ncp = look_ncp(nc1m)
    qca = look_qca(ncp)
    rc = look_relc(nc2)
    qc = look_qce(nc2)
    rt = find_rt(op)
    if rt[0] in 'aeiou':
        conjugrt = sc_vowel_vroot(rt,ncp)
    else:
        sc = look_sc(ncp)
        conjugrt = sc + rt
    return qca + ' ' + pl + ' ' + conjugrt + 'a' + ' ' + super + ' ' + rc + qc + 'dwa'
```

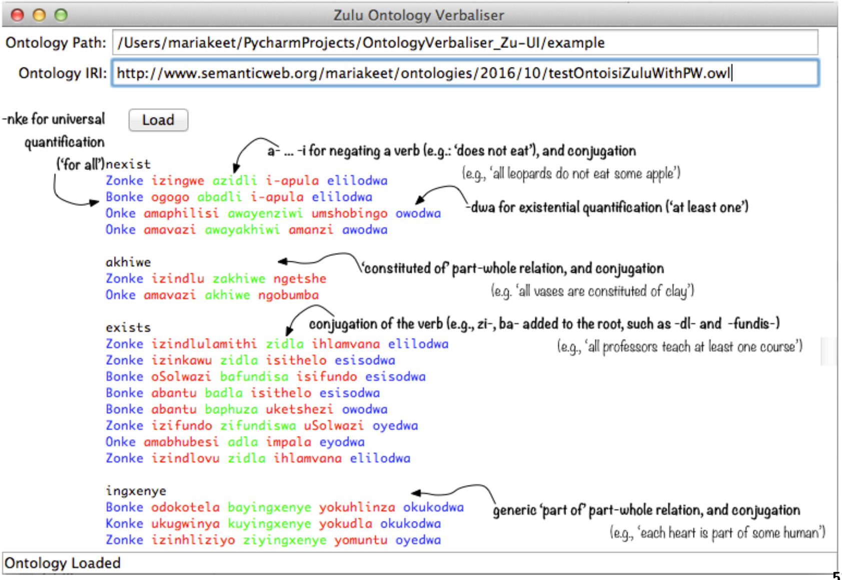
https://github.com/mkeet/GENIproject/

Proof-of-concept implementation (2/3)

```
<SubClassOf>
    <Class IRI="#indlovu"/>
    <Class IRI="#isilwane"/>
</SubClassOf>
<SubClassOf>
    <Class IRI="#indlovu"/>
    <ObjectSomeValuesFrom>
        <ObjectProperty IRI="#dla"/>
        <Class IRI="#ihlamvana"/>
    </ObjectSomeValuesFrom>
</SubClassOf>
```

https://github.com/mkeet/GENIproject/

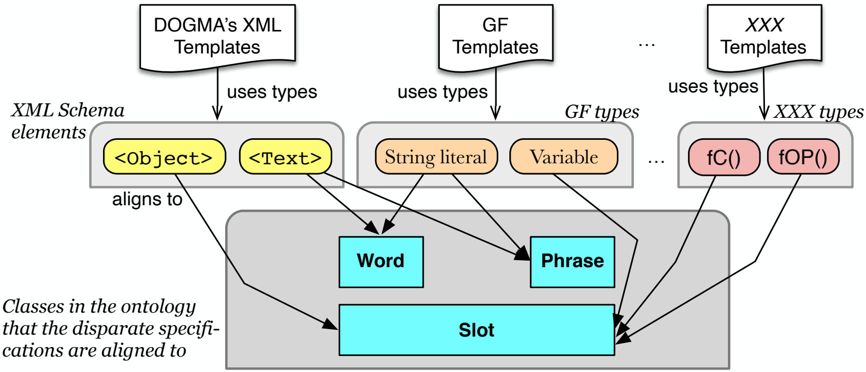
Sentences outputted as pretty printing or plaintext (3/3)



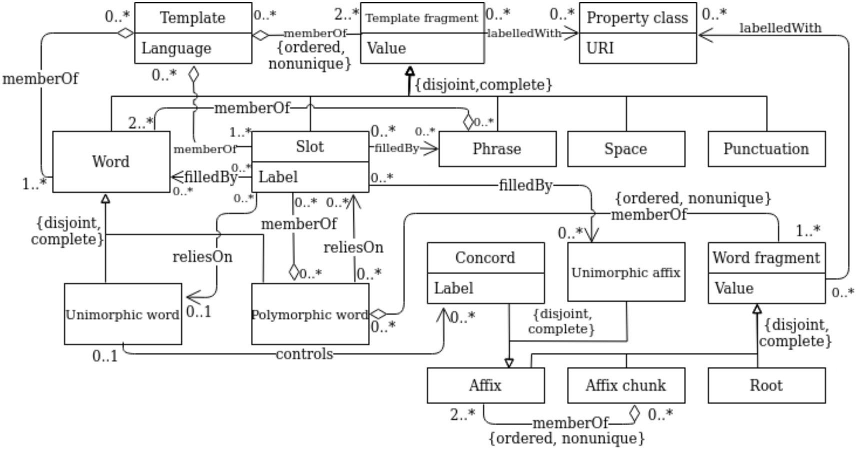
Toward a proper and modular surface realiser

- MoReNL project: http://www.meteck.org/moreNL/
- Architecture design [Mahlaza and Keet(2022)] and development
- Proof-of-concept realiser for isiZulu and isiXosa: https://github.com/AdeebNqo/NguniTextGeneration (Zola Mahlaza)
- Model for template languages [Mahlaza and Keet(2021)]
- GUI for template creation

An ontology for template languages?



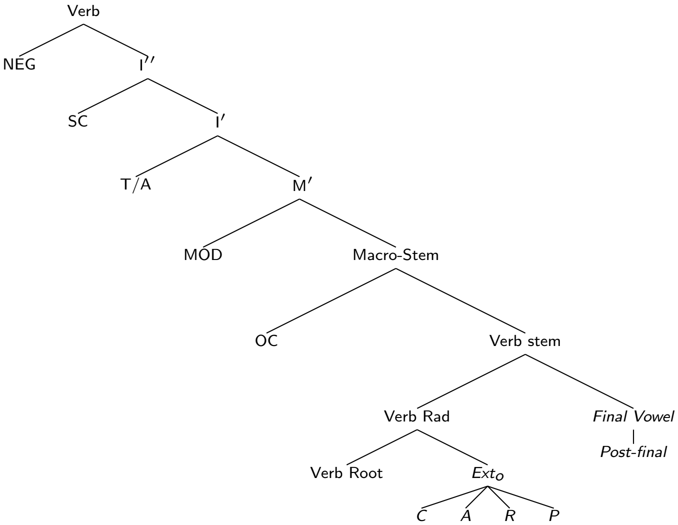
An ontology for template language: ToCT



[Mahlaza and Keet(2021)]

Outline

Figuring out the present tense [Keet and Khumalo(2017b)]



Figuring out the present tense [Keet and Khumalo(2017b)]

1. Verb, and start of the grammar:
   $v \rightarrow$ *pre vr post* a *wh* | *npre vr post* i *wh* | *ppre vr* e | *vr st* a | *excl s cont o vr post* a
2. Prefix (subject and object concord, tense, mode, and aspect):
   $pre \rightarrow$ *s* | *s m* | *s t m* | *s asp m* | *s o* | *s m o* | *s t m o* | *s asp m o*
3. Negative prefix (negation; e.g. 'does not' eat):
   $npre \rightarrow$ *ns* | *ns m* | *ns t m* | *ns asp m* | *ns o* | *ns m o* | *ns t m o* | *ns asp m o*
4. Postfix, begin the "CARP" extensions:
   $post \rightarrow$ *c* | *c a* | *c a r* | *c a p* | *c r* | *c r p* | *c p* | *c a r p* | *a* | *a r* | *a r p* | *a p* | *r* | *r p* | *p* | ε
5. List of subject concords and negative subject concords (terminals for conjugation):
   $s \rightarrow$ ngi | u | si | ni | ba | i | li | a | zi | lu | bu | ku | ε
   $ns \rightarrow$ angi | awu | aka | ali | asi | ayi | alu | abu | aku | ani | aba | awa | azi | ε
6. List of mod:
   $m \rightarrow$ a | e | ka | ma | nga | ε
7. List of tense (present (ε) and continuous (ya)tense; incomplete):
   $t \rightarrow$ ya | ε
8. List of aspect (additional rules omitted in this first iteration):
   $asp \rightarrow$ sa | se | be | ile | ε
9. List of object concords:
   $o \rightarrow$ ngi | si | ku | ni | m | ba | wu | yi | li | wa | zi | lu | bu | ε
10. Causative:
    $c \rightarrow$ is
11. Applicative:
    a $\rightarrow$ el
12. Reciprocative:
    $r \rightarrow$ an
13. Passive (with phonological conditioning options):
    p $\rightarrow$ iw | w
14. Politeness (own prefix system and a FV=e):
    $ppre \rightarrow$ *pl s*
    $pl \rightarrow$ aw | awu | mawu | ε | ma
15. Stative (insertion of the *-ek-* between the VR and the FV):
    $st \rightarrow$ ek
16. Wh-questions (in the post-final slot and are added at the end of the verb, being *-ni* 'what'/'who'/ 'why'/'how', *-nini* 'when', and *-phi* 'where'.):
    $wh \rightarrow$ ni | nini | phi | ε
17. 'Double aspect'/exclusive (with $excl \subset asp$)
    $excl \rightarrow$ se
18. Continuous tense (with $cont \subset t$):
    $cont \rightarrow$ ya
19. Lexicon of verb roots:
    $vr \rightarrow$ ab | ... | zwib

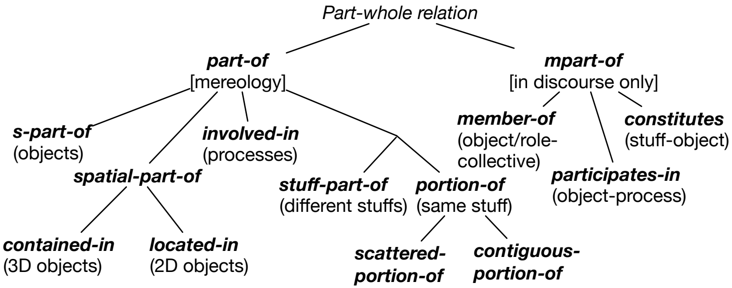
Extensions: part-whole relations

- Part-whole relations are used widely in medical and healthcare ontologies
- Many different types (23 in OpenGalen)
- Would that be convenient 1:1 translations?

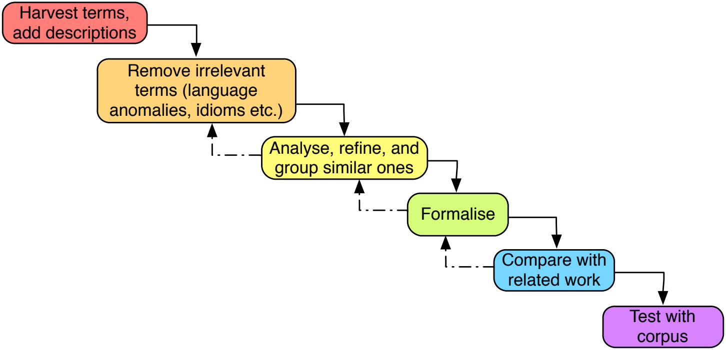
Extensions: part-whole relations

- Part-whole relations are used widely in medical and healthcare ontologies
- Many different types (23 in OpenGalen)
- Would that be convenient 1:1 translations?
  - No. both less and more specific ones: ontological differences
  - Other complications with verbs and prepositions
  - Details in: [Keet and Khumalo(2016)] [Keet(2017)] [Keet and Khumalo(2018)] [Keet and Khumalo(2020)]

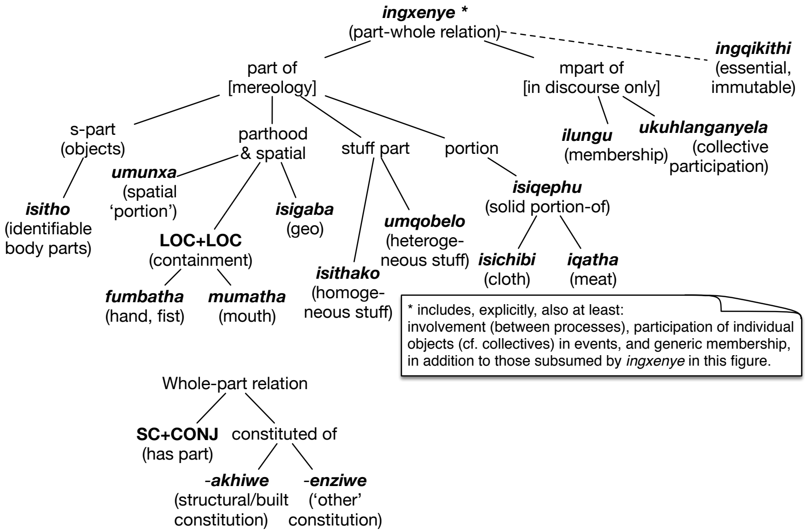
Part-whole relations: main differences [Keet and Khumalo(2020)]



Part-whole relations: main differences [Keet and Khumalo(2020)]



Part-whole relations: main differences [Keet and Khumalo(2020)]



Extensions: part-whole relations

- ‘part’ *ingxenye* + ‘of’ <PC for NC of *ingxenye* that’s then phonologically conditioned with noun of the whole>
    - e.g.: ‘part of a human’
      ingxenye ya- + *umuntu*
      ingxenye yomuntu

Extensions: part-whole relations

- ‘part’ *ingxenye* + ‘of’ <PC for NC of *ingxenye* that’s then phonologically conditioned with noun of the whole>
    - e.g.: ‘part of a human’
      ingxenye ya- + *umuntu*
      ingxenye yomuntu
- ‘contained in’: locative affixes on the object that plays the container role
    - Each bolus of food is contained in some stomach
    - ‘bolus of food’ *indilinga yokudla* (nc9)
    - ‘stomach’ *isisu* (nc7)
    - ‘is contained in’ : SC-EP-LOC-Whole-LOCSUF
    - zi-s-e-sis-wini (phonological conditioning: e+i=e and u+ini=wini)
    - *Zonke izindilinga zokudla zisesiswini esisodwa*

Outline

Further extensions and updates

- Adding (more) data-to-text to the knowledge-to-text
- Numbers, attributes (∼ adjectives), etc. etc.; e.g.:
  - engama-25 ([RC][COP][N prefix]-number)
  - Uqede imisebenzi eziyishumi 'You completed ten exercises', but amaphilisi ayishumi 'ten pills' [Keet(2021)]
  - izinkulungwane eziyisishiyagalombili namakhulu ayisishiyagalombili namashumi amane nane (numbers in speech cf. written)
- Option: application-driven prioritization for what to look into
- Rules-based approach is a slow process
- Limited documentation of language's grammar, often outdated, incomplete, or incorrect

Initial results for other languages

- Multilingual pluraliser [Byamugisha et al.(2018)]
- Bootstrapping NLG for Runyankore [Byamugisha et al.(2016)]: it's faster; (also shown by [Bosch et al.(2008)] for morphological analysers)

Initial results for other languages

- Multilingual pluraliser [Byamugisha et al.(2018)]
- Bootstrapping NLG for Runyankore [Byamugisha et al.(2016)]: it's faster; (also shown by [Bosch et al.(2008)] for morphological analysers)
- Bootstrappability strategies?
  - Trying to understand morphological and verb similarities as proxies [Keet(2016), Mahlaza and Keet(2019)]
  - Guthrie zones (not a good predictor) [Byamugisha(2019)]

What about ML and such for NLG?

- Feasibility of using machine learning or deep learning for templates:
  - Lack of good and relevant data (e.g., bible and Ubuntu software manual are out-of-domain for healthcare messages, old texts, OCR errors and typos)
  - Need comparatively more data (recall agglutination and type-to-token ratio)
  - Needs good NLU algorithms
  - Computing the language models is computationally expensive
  - The systems "hallucinate" and have spurious repetitions, in English at least
- Jan Buys at UCT commenced with that approach
- Other efforts: mashakane (corpus & MT) and Qfrency (TTS)

Outline

Summary

- Computational view on NCB languages wrt CNLs and NLG
- Resulted in novelties *both* in computing *and* in linguistics
- Toward a tailor-made grammar engine for surface realisation, with customisable templates
- NLG algorithms generic and modularised in the sense that they can be reused in other tools
- Low resource languages a challenge for both rule-based and data-driven approaches, but in different ways; take your pick

Collaborators and Funding

- Main linguist: Langa Khumalo (SADiLaR)
- Current/former students wrt NLG and ontologies: Mary-Jane Antia, Joan Byamugisha, Catherine Chavula, Takunda Chirema, Leighton Dawson, Francis Gillis-Webber, Zola Mahlaza, Sindiso Mkhatshwa, Junior Moraba, Gerald Ngumbulu, Toky Raboanary, Musa Xakaza, Steve Wang

- Main NRF grants: GeNI & MoRENL projects
  http://www.meteck.org/files/geni/
  http://www.meteck.org/MoReNL/

National Research Foundation
Hasso Plattner Institut
Digital Engineering • Universität Potsdam
science & innovation
Department: Science and Innovation
REPUBLIC OF SOUTH AFRICA
UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD
DOT4D
Digital Open Textbooks for Development
NATIONAL SCIENCE CENTRE
POLAND
UKRI
Engineering and Physical Sciences Research Council
UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

References I

Sonja Bosch, Laurette Pretorius, and Axel Fleisch.
Experimental bootstrapping of morphological analysers for nguni languages.
Nordic Journal of African Studies, 17(2):66–88, 2008.

J. Byamugisha, C.M. Keet, and B. DeRenzi.
Bootstrapping a runyankore cnl from an isizulu cnl.
In B. Davis et al., editors, *5th Workshop on Controlled Natural Language (CNL'16)*, volume 9767 of *LNAI*, pages 25–36. Springer, 2016.
25-27 July 2016, Aberdeen, UK.

J. Byamugisha, C. M. Keet, and B. DeRenzi.
Pluralizing nouns across agglutinating Bantu languages.
In *27th International Conference on Computational Linguistics (COLING'18)*, pages 2633–2643. ACL, 2018.
20-26 August, 2018, Santa Fe, New Mexico, USA.

Joan Byamugisha.
Ontology Verbalization in Agglutinating Bantu Languages: A Study of Runyankore and Its Generalizability.
Phd thesis, Department of Computer Science, November 2019 2019.

A. Gatt and E. Reiter.
Simplenlg: A realisation engine for practical applications.
In E. Krahmer and M. Theune, editors, *Proceedings of the 12th European Workshop on Natural Language Generation (ENLG'09)*, pages 90–93. ACL, 2009.
March 30-31, 2009, Athens, Greece.

References II

F. Gillis-Webber, S. Tittel, and C. M. Keet.
A model for language annotations on the web.
In *1st Iberoamerican conference on Knowledge Graphs and Semantic Web (KGSWC'19)*, volume 1029 of *CCIS*, pages 1–16. Springer, 2019.
24-28 June 2019, Villa Clara, Cuba.

Mustafa Jarrar, C. Maria Keet, and Paolo Dongilli.
Multilingual verbalization of ORM conceptual models and axiomatized ontologies.
Starlab technical report, Vrije Universiteit Brussel, Belgium, February 2006.
URL `http://www.meteck.org/files/ORMmultiverb_JKD.pdf`.

C. M. Keet.
An assessment of orthographic similarity measures for several african languages.
Technical Report Arxiv.org 1608.03065, University of Cape Town, August 2016.
URL `http://arxiv.org/abs/1608.03065`.

C. M. Keet.
Representing and aligning similar relations: parts and wholes in isizulu vs english.
In J. Gracia, F. Bond, J. McCrae, P. Buitelaar, C. Chiarcos, and S. Hellmann, editors, *Language, Data, and Knowledge 2017 (LDK'17)*, volume 10318 of *LNAI*, pages 58–73. Springer, 2017.
19-20 June, 2017, Galway, Ireland.

C. M. Keet and T. Chirema.
A model for verbalising relations with roles in multiple languages.
In E. Blomqvist, P. Ciancarini, F. Poggi, and F. Vitali, editors, *Proceedings of the 20th International Conference on Knowledge Engineering and Knowledge Management (EKAW'16)*, volume 10024 of *LNAI*, pages 384–399. Springer, 2016.
19-23 November 2016, Bologna, Italy.

References III

C. M. Keet and L. Khumalo.
Toward a knowledge-to-text controlled natural language of isiZulu.
Language Resources and Evaluation, 51(1):131–157, 2017a.
doi: 10.1007/s10579-016-9340-0.

C. M. Keet and L. Khumalo.
Grammar rules for the isizulu complex verb.
Southern African Journal of Language and Linguistics, 35(2):183–200, 2017b.

C. M. Keet and L. Khumalo.
On the ontology of part-whole relations in Zulu language and culture.
In S. Borgo and P. Hitzler, editors, *10th International Conference on Formal Ontology in Information Systems 2018 (FOIS'18)*, volume 306 of *FAIA*, pages 225–238. IOS Press, 2018.
17-21 September, 2018, Cape Town, South Africa.

C. Maria Keet.
Natural language generation requirements for social robots in subsaharan africa.
In P. Cunningham and M. Cunningham, editors, *IST-Africa 2021*, page 8p. IIMC International Information Management Corporation, 2021.
9-11 May, online.

C. Maria Keet and Langa Khumalo.
Toward verbalizing logical theories in isiZulu.
In B. Davis, T. Kuhn, and K. Kaljurand, editors, *Proceedings of the 4th Workshop on Controlled Natural Language (CNL'14)*, volume 8625 of *LNAI*, pages 78–89. Springer, 2014a.
20-22 August 2014, Galway, Ireland.

References IV

C. Maria Keet and Langa Khumalo.
Basics for a grammar engine to verbalize logical theories in isiZulu.
In A. Bikakis et al., editors, *Proceedings of the 8th International Web Rule Symposium (RuleML'14)*, volume 8620 of *LNCS*, pages 216–225. Springer, 2014b.
August 18-20, 2014, Prague, Czech Republic.

C. Maria Keet and Langa Khumalo.
On the verbalization patterns of part-whole relations in isizulu.
In *9th International Natural Language Generation conference (INLG'16)*, pages 174–183. ACL, 2016.
5-8 September, 2016, Edinburgh, UK.

C. Maria Keet and Langa Khumalo.
Parthood and part–whole relations in zulu language and culture.
Applied Ontology, 15(3):361–384, 2020.

C. Maria Keet, Musa Xakaza, and Langa Khumalo.
Verbalising owl ontologies in isizulu with python.
In Eva Blomqvist, Katja Hose, Heiko Paulheim, Agnieszka Lawrynowicz, Fabio Ciravegna, and Olaf Hartig, editors, *The Semantic Web: ESWC 2017 Satellite Events*, volume 10577 of *LNCS*, pages 59–64. Springer, 2017.
30 May - 1 June 2017, Portoroz, Slovenia.

Tobias Kuhn.
A principled approach to grammars for controlled natural languages and predictive editors.
Journal of Logic, Language and Information, 22(1):33–70, 2013.

Z. Mahlaza and C. M. Keet.
A method for measuring verb similarity for two closely related languages with application to zulu and xhosa.
South African Computer Journal, 31(2):34–56, 2019.

References V

Z. Mahlaza and C. Maria Keet.
Formalisation and classification of grammar and template-mediated techniques to model and ontology verbalisation.
Int. J. Metadata, Semantics and Ontologies, 14(3):249–262, 2020.

Z. Mahlaza and C. Maria Keet.
Surface realisation architecture for low-resourced african languages.
Submitted to an international Journal, page xx, 2022.

Z. Mahlaza and C.M. Keet.
Toct: A task ontology to manage complex templates.
In Emilio M. Sanfilippo et al., editors, *FOIS 2021 Ontology Showcase, The Joint Ontology Workshops (JOWO'21)*, volume 2969 of *CEUR-WS*, 2021.

E. Reiter and R. Dale.
Building applied natural language generation systems.
Natural Language Engineering, 3:57–87, 1997.

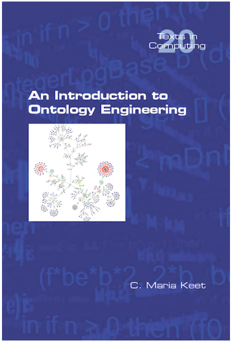
K. Winkler, T. Kuhn, and M Volk.
Evaluating the fully automatic multi-language translation of the swiss avalanche bulletin.
In B. Davis, T. Kuhn, and K. Kaljurand, editors, *Proceedings of the 4th Workshop on Controlled Natural Language (CNL'14)*, volume 8625 of *LNAI*, pages 44–54. Springer, 2014.
20-22 August 2014, Galway, Ireland.

Thank you!

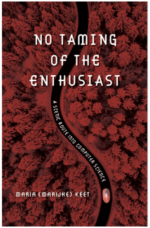
Questions?

My award-winning textbook

https://people.cs.uct.ac.za/~mkeet/OEbook/



A memoir



Some practical ‘loose ends’

- Where to best store the NC info needed for ontology verbalisation?
    - Ontolex-Lemon is good for declarative information, not for rules
    - Annotation model [Keet and Chirema(2016)]
    - And this for more NCB languages: WikiWorkshop 2022 abstract with a list of requirements[1]
- What if your language doesn’t have an ISO language tag?
    - Create your own!
    - e.g., with MoLA [Gillis-Webber et al.(2019)]
- Multilingual ontologies vs multiple monolingual ontologies, management thereof
- (There are more engineering questions to make it work)

[1] https://wikiworkshop.org/2022/papers/WikiWorkshop2022_paper_31.pdf