Overview Nguni Natural Language Generation

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MeMaT workshop, 4-5 December 2017

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Outline

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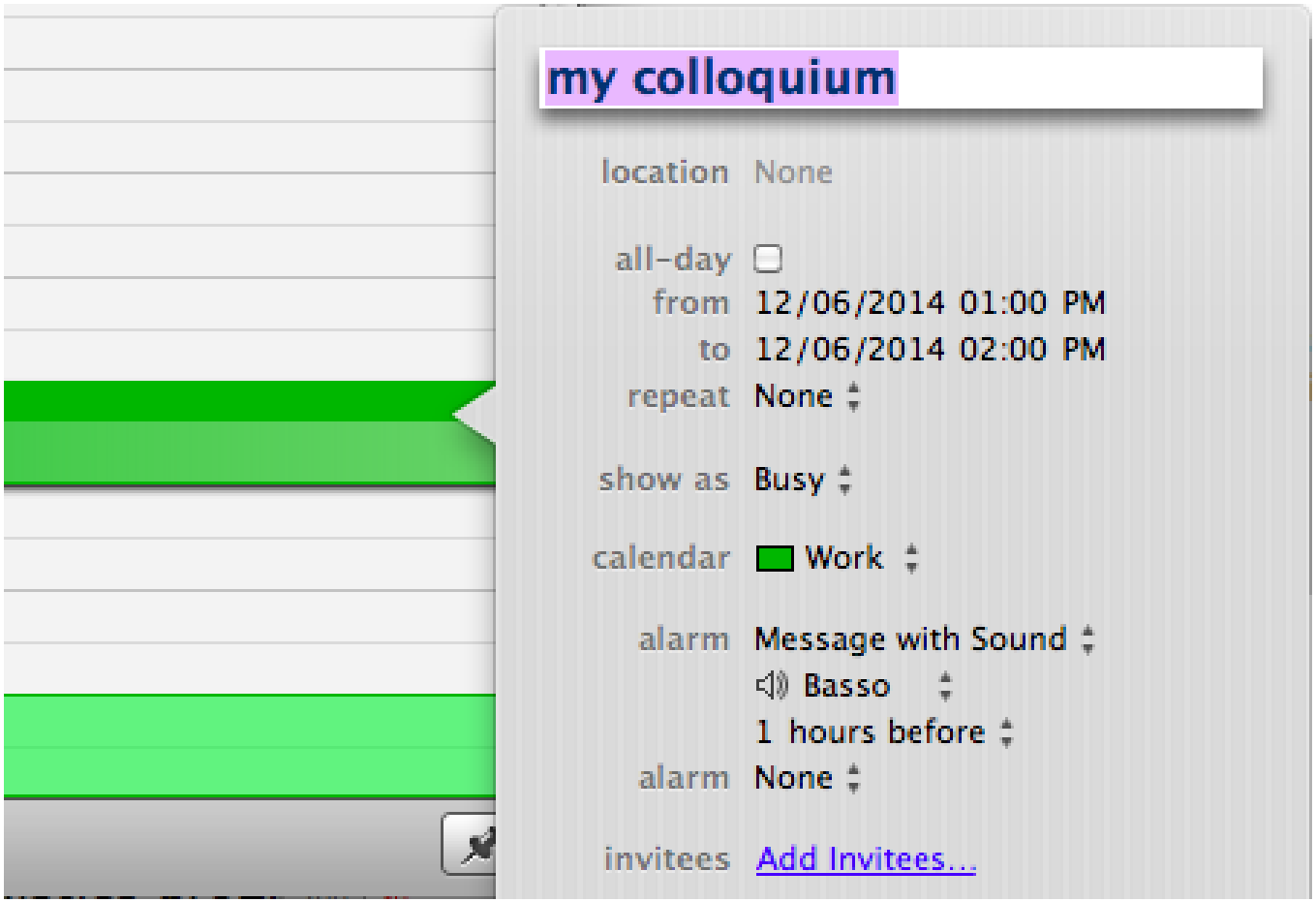
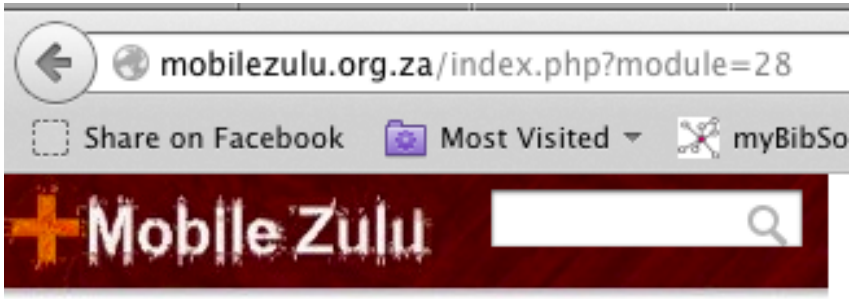
Natural language interfaces with some NLG

- 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.

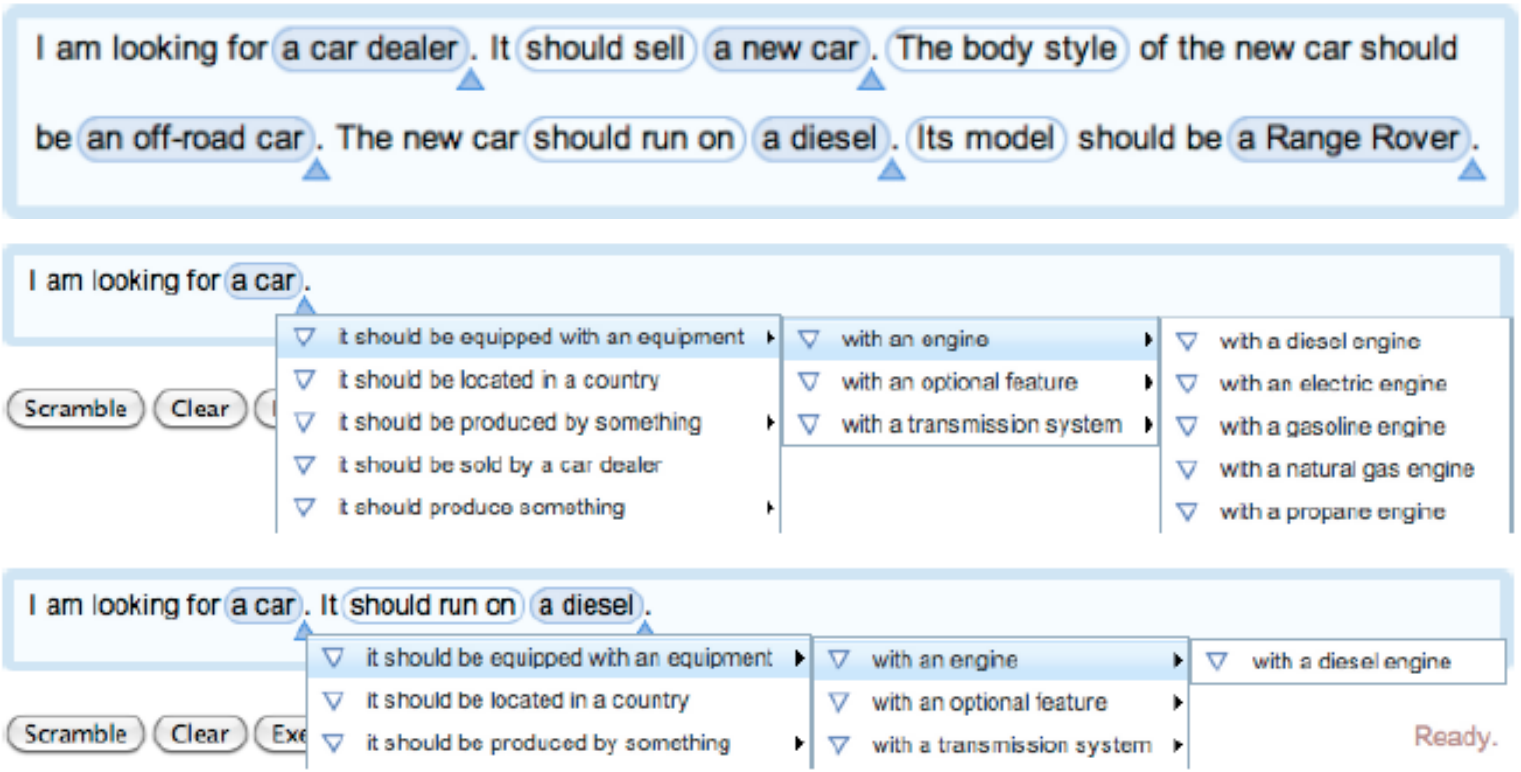
Example: iCal calendar entry with canned text



Example: Saadiq Moolla's mobile healthcare app



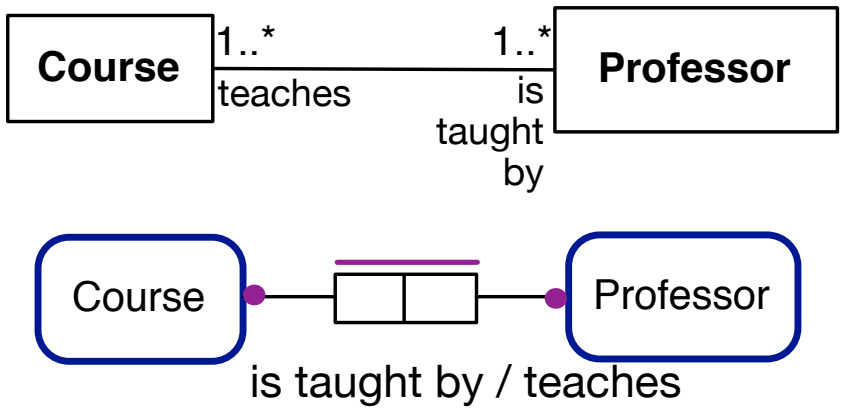
Example: Query formulation with Quelo [Franconi et al.(2010)]



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

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NLG, principal approaches

- 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)]
- Controlled Natural Language
- Grammar engines, such as [Kuhn(2013)], Grammatical Framework (`http://www.grammaticalframework.org/`)

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

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

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NL Grammars, illustration

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

(and complexity of the grammar)

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Questions

- Can the template-based approach be used also for isiZulu NLG? (2014)

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  - Non-1:1 mappings with isiZulu's 'part of' [Keet(2017)]
  - Language model to represent those components [Keet and Chirema(2016)]

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- Figure out more aspects of the verb (2016-2017)
  - Verb grammar [Keet and Khumalo(2017)]
- Grammar has been used to create and mark language learning exercises automatically

Logic foundation for isiZulu NLG

- Roughly OWL 2 EL
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- Tools, ontologies in OWL 2 (notably SNOMED CT)
- On the 'roughly': minus transitivity, but with negation, amounting to $\mathcal{ALC}$
  - of that, we have patterns for universal and existential quantification, subsumption, negation (disjointness), and conjunction
  - union not yet covered explicitly, but note $C \sqcup D \equiv \neg(\neg C \sqcap \neg D)$
  - more detail on the languages: see the Description Logics Handbook [Baader et al.(2008)] and OWL 2 Standard

Existential Quantification

- Common axiom type $C \sqsubseteq \exists R.D$ (named classes only)
- Example:

(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')
yonke indlulamithi idla noma yiliphi ihlamvana ('each giraffe eats some twig')
zonke izindlulamithi zidla noma yiliphi ihlamvana ('all giraffes eat some twig')
yonke indlulamithi idla ihlamvanathize ('each giraffe eats some twig')

Possible patterns for existential quantification

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.

b. <All-concord for NC_x>onke <pl. N_1, is in NC_x> <conjugated verb> noma <copulative *ng/y* adjusted to first letter of N_2><EP of NC_y>phi <N_2>.

c. <All-concord for NC_x>onke <N_1 in NC_x> <conjugated verb> <N_2>thize;

Example

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

Example

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

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

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

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

$\text{uSolwazi} \sqsubseteq \exists\ \text{ufun}\ldots$

look-up NC

pluralise

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-

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

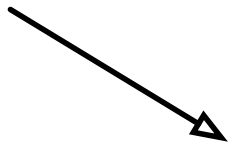
$\forall x\ (\text{uSolwazi}(x) \rightarrow \exists y\ (\text{ufundisa}(x, y) \wedge \text{Isifundo}(y)))$

$\text{uSolwazi} \sqsubseteq \exists(\text{ufundisa}.\text{Is}$

... for relevant NC. Here:

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

AlgoConjugate



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

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

uSolwazi $\sqsubseteq \exists$ ufundisa.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 lsifundo esisodwa

Screenshot of section of the verbaliser

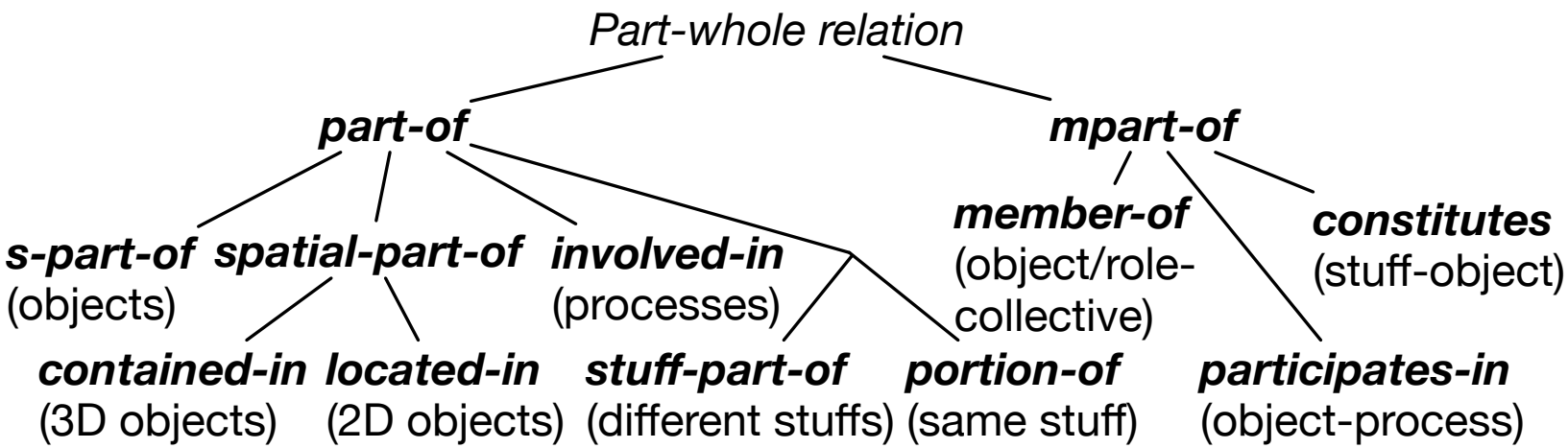
Zonke izindlovu zidla ihlamvana elilodwa	*last part of existential quantification* 'all elephants eat some twig'
ingxenye	
Bonke odokotela bayingxenye yokuhlinza okukodwa	*general part-whole relation* 'all doctors participate in some operation'
Konke ukugwinya kuyingxenye yokudla okukodwa	'all swallowing is involved in some eating'
Zonke izinhliziyo ziyingxenye yomuntu oyedwa	'all hearts are part of some human'
Bonke abanumzana bayingxenye yeNgqungquthela eyodwa	'all Mr.s participate in some conference'
hlanganyele	
Wonke umphakathi uhlanganyele okhethweni olulodwa	*collective-group* 'all electorates participate in some election'
aaaa	
Zonke iziNgqungquthela zinoMnumzana oyedwa	*general whole-part relation* 'all conferences have as participant some Mr.s'

More details: ESWC'17 demo paper [Keet et al.(2017)]

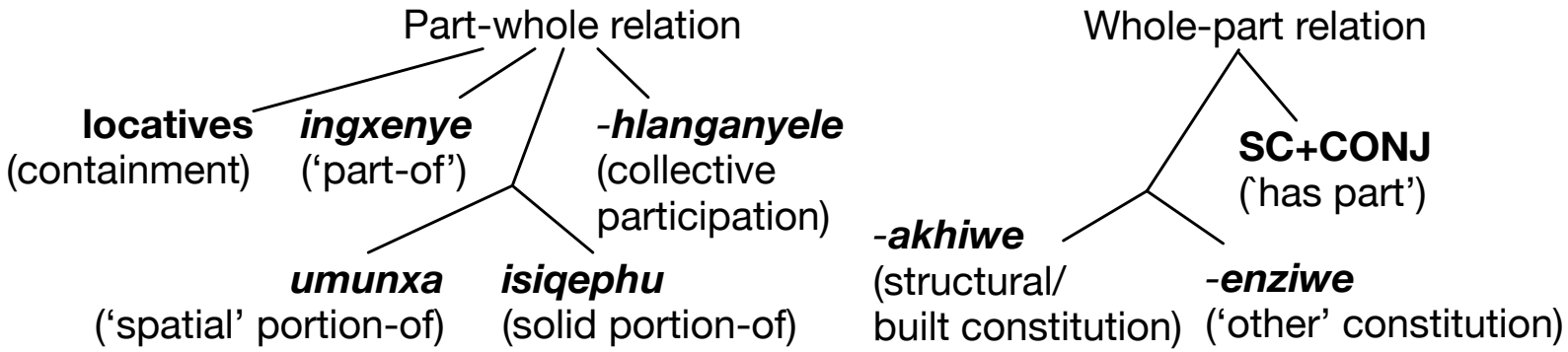
`http://www.meteck.org/files/geni/VerbaliserisiZuluScreencast.mov`

Outline

Common part-whole relations



Attempt at structuring part-whole relations in isiZulu



- Less discriminating: *ingxenye*/SC+CONJ used for parthood, involvement, membership, stuff parts, participation of individual objects (vs. collectives), containment (w-p only)
- More discriminating: portions, participation, and constitution

Context-dependent surface realisation (no single label)

- Common medical ontologies axioms type $C \sqsubseteq \exists R.D$
- Verbalisation pattern if R='has part':
  $\mathrm{QCall}_{nc_{x,pl}}$ $\mathrm{W}_{nc_{x,pl}}$ $\mathbf{SC}_{nc_{x,pl}}$-**CONJ**-P_{nc_y} RC_{nc_y}-QC_{nc_y}-*dwa*
- SC 'conjugation' dependent on noun class of head noun (that plays the Whole)
- CONJ 'conjunction' phonologically conditioned *na-*
- 6 SCs for plurals, 3 CONJ variants = 18 cases

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- 6 SCs for plurals, 3 CONJ variants = 18 cases
- Examples:
  - *bonke abantu banenhliziyo eyodwa*
    'All humans have as part some heart'
    abantu nc=2, *na+inhliziyo=nenhliziyo*
  - W='orchestra' (nc5, SC=*a-*) and P='musician' *isazi somnyuziki* → *anesazi somnyuziki*
  - W='computer' (nc5) and P='CPU' *umqondo womshini* → *anomqondo womshini*

Attempt at structuring part-whole relations in isiZulu

Contain-ment of objects

Whole->part Qcall(nc(x,pl)) W(nc(x,pl)) **SC(nc(x,pl))-CONJ**-P(nc(y)) RC(nc(y))-QC(nc(y))-*dwa*

Part->whole Qcall(nc(x,pl)) P(nc(x,pl)) **SC(nc(x,pl)-EP-LOC-W(nc(y)) -LOCSUF** RC(nc(y))-QC(nc(y))-*dwa*

Ex. W->p: Zonke izisu ***zi-*** ***ne-*** *ndilinga yokudla e-yo-dwa*
All stomachs have and bolus of food at least one

Ex. P->w: Zonke izindilinga zokudla ***zi-s-e-*** *sis-* ***wini*** *esi-so-dwa*
All boluses of food are contained stomach in at least one

Outline

Discussion

- Template-based approach is not applicable to isiZulu (and, more generally: Bantu languages that have noun classes)
  - Or: grammar engine needed
- Devising the patterns hampered by outdated literature
- Several preferences for patterns
- Algorithms nontrivial; covering:
  - 'simple' existential and universal quantification
  - taxonomic subsumption
  - negation (class disjointness)
  - conjunction
- Essentially contributing to documenting the grammar

Some other potential use: machine translation

- Google's "all giraffes eat twigs" is translated as "*yonke izindlulamithi udle amahlumela*" (d.d. 14-1-2014) and as *wonke ama-giraffe adle amahlumela* (d.d. 3-12-2017)
  - But *izindlulamithi* is in noun class 10, so it goes with *zonke*; correct with our algorithms
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- Other issues that will be not easy for the statistical language approach: deep prepositions, part-whole relations, phonological conditioning, ...
- Some fun on the next page

Google Translate English-isiZulu (d.d. 3-12-2017)

- (1) 'swallowing is involved in eating' → *ukugwinya kuhileleka ekudleni* → 'swallowing involves eating'
  (2) 'all swallowing is involved in some eating' → *konke ukugwinya kubandakanyeka ekudleni abanye* → 'all swallowing is involved in eating others'

[2] https://bwisehealth.com/article/how-healthy-are-your-friendships?lang=zulu

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- (1) 'All humans have as part some heart' → *Bonke abantu banengxenye yenhliziyo* → 'All people have a part of the heart'
  (2) 'All humans have as part at least one heart' → *Bonke abantu banengxenye okungenani inhliziyo eyodwa* → 'All people have at least one part' (...)
  (3) 'All humans have part at least one heart' → *Bonke abantu banenkani okungenani inhliziyo eyodwa* → 'All people are stubborn at least one heart'

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- (1) 'all doctors participate in some operation' → *bonke odokotela bahlanganyela ekusebenzeni okuthile* → 'all doctors participate in some work'
  (2) 'all electorates participate in at least one election' → *bonke abakhethiweyo bahlanganyela okungenani ukhetho olulodwa* → 'all the candidates participate at least one option'
- (1) 'All humans have as part some heart' → *Bonke abantu banengxenye yenhliziyo* → 'All people have a part of the heart'
  (2) 'All humans have as part at least one heart' → *Bonke abantu banengxenye okungenani inhliziyo eyodwa* → 'All people have at least one part' (...)
  (3) 'All humans have part at least one heart' → *Bonke abantu banenkani okungenani inhliziyo eyodwa* → 'All people are stubborn at least one heart'
- (1) *Abangani esibagcinayo banengxenye abayidlalayo enkulu empilweni esiyiphilayo*[2] → 'The friends we care about have a major part of our life' → *Abangane esibakhathalelayo banengxenye enkulu yokuphila kwethu*
  (2) *Kwamanye, banengxenye izifo, kungenzeka isisindo somzimba, kanye nezinguquko isimo ngokomzwelo kuhlanganise nemizwelo eguquguqukayo*[3] → 'In some cases, they have infections, possibly weight loss, and emotional changes as well as flexible emotions' → *Kwezinye izimo, banezinkinga, mhlawumbe ukulahlekelwa isisindo, nezinguquko zomzwelo kanye nemizwelo eguquguqukayo*

[2] https://bwisehealth.com/article/how-healthy-are-your-friendships?lang=zulu

[3] https://steroidio.com/zu/steroids-list/

Outline

Conclusions

- Knowledge-based approach to NLG
- Novel verbalisation patterns and algorithms for simple subsumption, disjoint classes, conjunction, and basic options with quantification
- Verbalising formally represented knowledge in isiZulu requires a grammar engine even for the relatively basic language constructs
- Due to, principally: i) the system of noun classes, ii) the system of complex agreement, iii) phonological conditioned copulatives, and iv) verb conjugation
- Other basic language model for annotation of verbs and nouns with deep prepositions
- Part-whole relations

Future work

- More constructors
- Conjugation of verbs other tenses, and more prepositions (taught *by*, works *for*)
- Phonological conditioning in a structured fashion
- More systematic way for the 'patterns'
- Interaction with data-driven approaches (learning and verification)

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Thank you!

GeNi project details:
`http://www.meteck.org/files/geni/`

Questions?