Towards a Truly Statistical Natural Language Generator for Spoken Dialogues

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Introduction

Objective of NLG
Given (whatever) input and a communication goal, create a natural language string that is well-formed and human-like.

- Desired properties: simplicity, variation, trainability …

Usage

- Spoken dialogue systems
- Machine translation
- Short texts: weather reports, customer recommendation …
- Summarization
- Question answering in knowledge bases
Standard NLG Pipeline (*Textbook*)

**[Input]**

- Content/Text Planning (“what to say”)
  - Content selection, basic structuring (ordering)

**[Text plan]**

- Sentence Planning/Realization (“how to say it”)
- Microplanning: aggregation, lexical choice, referring...

**[Sentence Plan(s)]**

- Surface realization: linearization according to grammar

**[Text]**

Towards a Truly Statistical Natural Language Generator
Real NLG Systems

Few systems implement the whole pipeline

- Systems focused on content planning with trivial surface realization
- Surface-realization-only systems
- Word-order-only systems
- Input/intermediate data representation varies greatly

Possible approaches

- Rule/template-based (if-then-else, filling in slots)
- Grammar-based (various formalisms, e.g. FUG, CCG)
- Only since 2000s: Statistical ... or rather hybrid
Introducing Statistical Methods to NLG

Rule-based methods

- Simple, straightforward, fast
- Surface realizers: once and for all
- Reliable (important!)
  - Content plans custom-tailored for domain
  - Surface realizer sure to produce grammatical output

Statistical methods

- Easier to maintain
- Easily adaptable to new domains
- Robust to unseen input
- Add variation, (hopefully) naturalness
Trainable Content Planning: User Models

- Presentation strategy based on user model
  - initial questions
- Adaptive, but rule-based
- MATCH, GEA, FLIGHTS

\[ U_h = \sum_{k=1}^{K} w_k u_k(x_{kh}) \]

- \( U_h \)…total utility of option \( h \)
- \( u_k(x_{kh}) \)…utility of \( k \)-th attribute
- \( w_k \)…user-specific weight of \( k \)-th attribute
Trainable Content Planning: Overgenerate and Rank

- Rule-based sentence plan generator (clause combining operations)
  - Randomly sample several sentence plans
- Reranker (RankBoost) trained on hand-annotated sentence plans
  - Rank plans and select the best one
- **SPoT**

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<table>
<thead>
<tr>
<th>Alt</th>
<th>Realization</th>
<th>H</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>What time would you like to travel on September the 1st to Dallas from Newark?</td>
<td>5</td>
<td>.85</td>
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<tr>
<td>5</td>
<td>Leaving on September the 1st. What time would you like to travel from Newark to Dallas?</td>
<td>4.5</td>
<td>.82</td>
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<tr>
<td>8</td>
<td>Leaving in September. Leaving on the 1st. What time would you, traveling from Newark to Dallas, like to leave?</td>
<td>2</td>
<td>.39</td>
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</table>
Trainable Content Planning: Reinforcement Learning

- Reinforcement learning of presentation strategy
- Communicative Goal: Dialogue Act + desired user reaction
- Plan lower-level NLG actions to achieve goal
- Markov Decision Process

$$Q^\pi(s, a) = \sum_{s'} T^a_{ss'} \left( R^a_{ss'} + \gamma V^\pi(s') \right)$$

- RL-NLG
Trainable Surface Realizers: Overgenerate and Rank

- Require a handcrafted realizer, e.g. CCG realizer
- Input underspecified $\rightarrow$ more outputs possible
- Overgenerate
- Then use a statistical reranker
- Ranking according to:
  - \textit{NITROGEN}, \textit{HALOGEN}: \textit{n}-gram models
  - \textit{FERGUS}: Tree models (XTAG grammar)
  - \textit{Nakatsu and White}: Predicted Text-To-Speech quality
  - \textit{CRAG}: Personality traits (extraversion, agreeableness...)
    + alignment (repeating words uttered by dialogue counterpart)
- Provides variance, but at a greater computational cost
Trainable Surface Realizers: Parameter Optimization

- Still require a handcrafted realizer
- Train handcrafted realizer parameters
- No overgeneration
- Realizer needs to be “flexible”

Examples

- *Paiva and Evans*: linguistic features annotated in corpus generated with many parameter settings, correlation analysis
- *PERSONAGE–PE*: personality traits connected to linguistic features via machine learning
Statistical Surface Realizers

Using methods of Machine Translation

- “translating” from semantic representation to text
- \textit{PHARAOH SMT} / synchronous CFG + MaxEnt (\textit{WASP}^{-1})
- hybrid trees with CRFs (\textit{TreeCRF})

Syntax-based

- \textit{Bohnet et al.}: pipeline model with SVMs
- Meaning-Text Theory
- Semantics $\rightarrow$ Syntax $\rightarrow$ Linearization $\rightarrow$ Morphologization
Fully Statistical Natural Language Generators

- Few, based on supervised learning
- Limited domain
- Hierarchical, phrase-based
- *Mairesse et al.*: Bayesian networks
  - semantic stacks
- *Angeli et al.*: log-linear model
  - records → fields → templates

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<tr>
<th>Charlie Chan name inform</th>
<th>is a inform</th>
<th>Chinese food inform</th>
<th>restaurant type inform</th>
<th>near inform</th>
<th>Cineworld near inform</th>
<th>in the inform</th>
<th>centre of town inform</th>
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<tr>
<td>t = 1</td>
<td>t = 2</td>
<td>t = 3</td>
<td>t = 4</td>
<td>t = 5</td>
<td>t = 6</td>
<td>t = 7</td>
<td>t = 8</td>
</tr>
</tbody>
</table>
Language Generation at ÚFAL: Current State

Prior work

- For Czech
- Surface realization only, rule-based
- Based on FGD, tecto-trees
  - Functors / formemes
- Ptáček and Žabokrský, TectoMT

NLG for Dialogue Systems

- Mixing templates and tecto-trees
  
  \[
  \text{Vlak} \quad \text{[Praha|n:do+2|gender:fem]} \\
  \text{jede v} \quad [[7|adj:attr] \text{hodina|n:4|gender:fem}].
  \]

- Statistical word form generator (*Flect*)
Prospects

Desired properties of a new NLG system for dialogues

- **Trainable**: simple domain adaptation
- **Variable**: no fixed templates
- **Multilingual**: Czech and English at the very least

Planned approach

- *FGD*, tecto-trees as a useful formalism
- Surface realizer at least partially trainable
  - Many grammar rules can be learned from corpora
  - Statistical morphology generation: avoiding dictionaries
- Content planner fully trainable
  - Using MT-inspired methods for content planning?
Thank You

You can find these slides, including references, at:

You can contact me at:
odusek@ufal.mff.cuni.cz
## References

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
<th>Journal/Conference</th>
</tr>
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<tbody>
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<td>Bohnet, B. et al.</td>
<td>Broad coverage multilingual deep sentence generation with a stochastic multi-level realizer.</td>
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<td>Adapting Chart Realization to CCG.</td>
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<td>Individuality and alignment in generated dialogues.</td>
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<td>Bangalore, S. and Rambow, O.</td>
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<td>Demberg, V. and Moore, J.</td>
<td>Information presentation in spoken dialogue systems.</td>
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<td>An empirical verification of coverage and correctness for a general-purpose sentence generator.</td>
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<td>Mairesse, F. et al.</td>
<td>Phrase–based statistical language generation using graphical models and active learning.</td>
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<td>Nakatsu, C. and White, M.</td>
<td>Learning to say it well: reranking realizations by predicted synthesis quality.</td>
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<td>Generation that exploits corpus–based statistical knowledge.</td>
<td><em>ACL–COLING</em></td>
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<td>Empirically–based control of natural language generation.</td>
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TectoMT  Žabokrtský, Z. et al. 2008. TectoMT: highly modular MT system with tectogrammatics used as transfer layer. WMT


WASP  Wong, Y. W. and Mooney, R. J. 2007. Generation by inverting a semantic parser that uses statistical machine translation. NAACL


Further NLG Links
C. DiMarco's slides: https://cs.uwaterloo.ca/~jchampai/CohenClass.en.pdf
J. Moore's NLG course: http://www.inf.ed.ac.uk/teaching/courses/nlg/
NLG Systems Wiki: http://www.nlg-wiki.org

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