NNLG
Neural Natural Language Generation

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Joint work with
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Introduction

Communicative Goal

Input

Content Planning → Sentence Planning → Surface Realization → Text
Introduction

- Records / Fields / Values
- Source Code
- Predicate-Argument Structure
- Algebra equation
- Text / Script
- Multi-modal sources
Introduction

- Records / Fields / Values
- Source Code
- Predicate-Argument Structure
- Algebra equation
- Text / Script
- Multi-modal sources

- Single utterance
- Single (complex) sentence
- Multiple sentences
- Multiple paragraphs
Introduction

- Records / Fields / Values
- Source Code
- Predicate-Argument Structure
- Algebra equation
- Text / Script
- Multi-modal sources

- Single utterance
- Single (complex) sentence
- Multiple sentences
- Multiple paragraphs

✔ What is the best input representation?

✔ How can we model document structure?

✔ How do we know that we have done well?
Concept-to-Text Generation

(A Global Model for Concept-to-Text Generation. Konstas and Lapata, JAIR 2013.)
Concept-to-Text Generation

Input: Machine-generated Representation

(A Global Model for Concept-to-Text Generation. Konstas and Lapata, JAIR 2013.)
Concept-to-Text Generation

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Concept-to-Text Generation

Input: Machine-generated Representation

<table>
<thead>
<tr>
<th>source</th>
<th>block:</th>
<th>hk</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>block:</td>
<td>ms</td>
</tr>
<tr>
<td>pos</td>
<td>RP:</td>
<td>W</td>
</tr>
</tbody>
</table>
Concept-to-Text Generation

Input: Machine-generated Representation

source | block: | hk
---|---|---
target | block: | ms
pos | RP: | W scale: small

Place the heineken block west of the mercedes block.

(A Global Model for Concept-to-Text Generation. Konstas and Lapata, JAIR 2013.)
Code-to-Text Generation

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Code-to-Text Generation

*Input: Source Code*

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Code-to-Text Generation

Input: Source Code

CODER-NN

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Code-to-Text Generation

Input: Source Code

CODE-NN

```csharp
public int TextWidth (string text) {
    TextBlock t = new TextBlock();
    t.Text = text;
    return (int) Math.Ceiling(t.ActualWidth);
}
```

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Code-to-Text Generation

**Input:** Source Code

CODE-NN

```csharp
public int TextWidth (string text) {
    TextBlock t = new TextBlock();
    t.Text = text;
    return (int)Math.Ceiling(t.ActualWidth);
}
```

Get rendered width of string rounded up to the nearest integer.

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Meaning Representation Generation

*Input:* Predicate - Argument Structure

(Flanigan et al, NAACL 2016, Pourdamaghani and Knight, INLG 2016, Song et al, EMNLP 2016.)
Meaning Representation Generation

**Input:** Predicate - Argument Structure

I knew a planet that was inhabited by a lazy man.

(Flanigan et al, NAACL 2016, Pourdamaghani and Knight, INLG 2016, Song et al, EMNLP 2016.)
Meaning Representation Generation

\[
\text{Input: Predicate - Argument Structure}
\]

I knew a planet that was \textit{inhabited} by a lazy man.

I have \textit{known} a planet that was \textit{inhabited} by a lazy man.

(Flanigan et al, NAACL 2016, Pourdamaghani and Knight, INLG 2016, Song et al, EMNLP 2016.)
Meaning Representation Generation

*Input*: Predicate - Argument Structure

- I knew a **planet** that was **inhabited** by a **lazy** man.
- I have known a **planet** that was **inhabited** by a **lazy** man.
- I know a **planet**. It is **inhabited** by a **lazy** man.

(Flanigan et al, NAACL 2016, Pourdamaghani and Knight, INLG 2016, Song et al, EMNLP 2016.)
Instructional Text Generation
Instructional Text Generation

*Input*: Goal Cue - Bag of concepts
Spanakopita
(Greek Spinach Pie)

**Ingredients**

- 3 tbsp olive oil
- 1 large onion, chopped
- 1 bunch green onions
- 2 cloves garlic, minced
- 2 pounds spinach
- 1/2 cup chopped fresh parsley
- 2 eggs
- 1/2 cup ricotta cheese
- 1 cup feta cheese
- 8 sheets filo dough
- 1/4 cup olive oil

*Input: Goal Cue - Bag of concepts*

(Globally Coherent Text Generation with Neural Checklist Models. Kiddon et al, EMNLP 2016.)
Spanakopita (Greek Spinach Pie)

**Ingredients**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>olive oil</td>
<td>3 tbsp</td>
</tr>
<tr>
<td>large onion, chopped</td>
<td>1</td>
</tr>
<tr>
<td>bunch green onions</td>
<td>1</td>
</tr>
<tr>
<td>cloves garlic, minced</td>
<td>2</td>
</tr>
<tr>
<td>spinach</td>
<td>2 pounds</td>
</tr>
<tr>
<td>chopped fresh parsley</td>
<td>1/2 cup</td>
</tr>
<tr>
<td>ricotta cheese</td>
<td>1/2 cup</td>
</tr>
<tr>
<td>feta cheese</td>
<td>1 cup</td>
</tr>
<tr>
<td>filo dough</td>
<td>8 sheets</td>
</tr>
<tr>
<td>olive oil</td>
<td>1/4 cup</td>
</tr>
</tbody>
</table>

**Instructions**

Preheat oven to 350 degrees F (175 degrees C). Lightly oil a 9x9 inch square baking pan.

Heat 3 tablespoons olive oil in a large skillet over medium heat. Saute onion, green onions and garlic, until soft and lightly browned. Stir in spinach and parsley, and continue to saute until spinach is limp, about 2 minutes. Remove from heat and set aside to cool.

In a medium bowl, mix together eggs, ricotta, and feta. Stir in spinach mixture. Lay 1 sheet of phyllo dough in prepared baking pan, and brush lightly with olive oil. Lay another sheet of phyllo dough on top, brush with olive oil, and repeat process with two more sheets of phyllo. The sheets will overlap the pan. Spread spinach and cheese mixture into pan and fold overhanging dough over filling. Brush with oil, then layer remaining 4 sheets of phyllo dough, brushing each with oil. Tuck overhanging dough into pan to seal filling.

Bake in preheated oven for 30 to 40 minutes, until golden brown. Cut into squares and serve while hot.

(Globally Coherent Text Generation with Neural Checklist Models. Kiddon et al, EMNLP 2016.)
Story Generation

*Input*: Script - Text - N/A
Jim was obsessed with super heroes. His sister told him if he tied a sheet on his back he could fly. She convinced Jim to climb the ladder to the roof and jump off. When he got up there he felt like he was superman.
Jim was obsessed with super heroes. His sister told him if he tied a sheet on his back he could fly. She convinced Jim to climb the ladder to the roof and jump off. When he got up there he felt like he was superman. He ended up having a great time!
Jim was obsessed with super heroes.
His sister told him if he tied a sheet on his back he could fly.
She convinced Jim to climb the ladder to the roof and jump off.
When he got up there he felt like he was superman.

He ended up having a great time!

Jim broke his arm and his sister was grounded for a year.

(Work with Li Zilles)
Story Generation (2)

*Input*: Equation + Theme

(Koncel-Kedziorski, Konstas, Zettlemoyer, Hajishirzi. A Theme-Rewriting Approach for Generating Algebra Word Problems. EMNLP 2016.)
Story Generation (2)

*Input:* Equation + Theme


\[ 504 + x = 639 \]
Luke Skywalker has 639 blasters. Leia has 504 blasters. How many more blasters does Luke Skywalker have than Leia?

\[504 + x = 639\]

(Koncel-Kedziorski, Konstas, Zettlemoyer, Hajishirzi. A Theme-Rewriting Approach for Generating Algebra Word Problems. EMNLP 2016.)
NNLG Framework
NNLG Framework

input
NNLG Framework

input → Encoder
The A knew a planet inhabited was...
think :arg0 you :arg1 quest

what
do
you
think
? 
</s>
Encoding
Encoding

Bag of Words

```sql
SELECT max(marks) FROM stud_records WHERE marks < (SELECT max(marks) FROM stud_records);
```
Encoding

Bag of Words

CODE-NN

\[
\text{SELECT max(marks) FROM stud_records WHERE marks < (SELECT max(marks) FROM stud_records)};
\]

\[
\text{SELECT max(col0) FROM tab0 WHERE col0 < (SELECT max(col1) FROM tab1)};
\]

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Encoding

Bag of Words

CODE-NN

```
SELECT max(marks) FROM stud_records WHERE marks < (SELECT max(marks) FROM stud_records);
```

anonymization

```
SELECT max(col0) FROM tab0 WHERE col0 < (SELECT max(col1) FROM tab1);
```

(Summarizing Source Code using a Neural Attention Model. Iyer, Konstas, Cheung, Zettlemoyer. ACL 2016.)
Encoding

Linearize —> RNN encoding

MR Generation
Encoding

Linearize —> RNN encoding

MR Generation

know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy
Encoding

Linearize —> RNN encoding

MR Generation

know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy
Encoding

Linearize —> RNN encoding

MR Generation

know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy
Encoding

Linearize —> RNN encoding

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know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy
Encoding

Linearize —> RNN encoding

MR Generation

know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy
Encoding

Hierarchical RNN encoding  Story Generation
Jim was obsessed with superheroes. His sister told him if he tied a sheet on his back he could fly. She convinced Jim to climb the ladder to the roof and jump off. When he got up there he felt like he was superman.
Encoding

Hierarchical RNN encoding

Story Generation

Jim was obsessed with superheroes.
His sister told him if he tied a sheet on his back he could fly.
She convinced Jim to climb the ladder to the roof and jump off.
When he got up there he felt like he was superman.
Jim was obsessed with superheroes.
His sister told him if he tied a sheet on his back he could fly.
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Jim was obsessed with superheroes.
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She convinced Jim to climb the ladder to the roof and jump off.
When he got up there he felt like he was superman.
Decoding

Beam search (Left-to-Right)
Decoding

Beam search (Left-to-Right)
Decoding

Beam search (Left-to-Right)
Decoding

Beam search (Left-to-Right)

h_{N(s)}

I
The
A

... ⨕

know
knew
planet

... ⨕

w_{11}: I

w_{12}: The

w_{13}: Man

w_{14}: Tree

...
Decoding

Beam search (Left-to-Right)

\[ h_N(s) \rightarrow I \rightarrow \text{The} \rightarrow A \rightarrow \ldots \rightarrow \text{know} \rightarrow \text{knew} \rightarrow \text{planet} \rightarrow \ldots \rightarrow \text{a} \rightarrow \text{planet} \rightarrow \text{man} \rightarrow \ldots \]

\[ w_{11}: I \quad w_{21}: I \text{ know} \]
\[ w_{12}: \text{The} \quad w_{22}: I \text{ knew} \]
\[ w_{13}: \text{Man} \quad w_{23}: \text{The planet} \]
\[ w_{14}: \text{Tree} \quad w_{24}: \text{Man planet} \]
\[ \ldots \quad \ldots \]
Decoding

Beam search (Left-to-Right)

I know a planet

\[ h_N(s) \]

\[ h_1(s) \]

\[ h_2(s) \]

\[ h_3(s) \]

\[ h_4(s) \]

\[ h_5(s) \]
Decoding

Beam search (Left-to-Right)

The planet...
Attention

\( h_2^{(t)} \) \( \rightarrow \) \( h_3^{(t)} \)

\( w_2: \text{know} \)

the planet
man

...
Attention

know → h₁

ARG0 → h₂

I → h₃

ARG1 → h₄

planet → h₅

h₂ \( (t) \) → c₂ → h₃ \( (t) \)

w₂: know

the planet man ...

Attention

know → h₁(s)
ARG0 → h₂(s)
I → h₃(s)
ARG1 → h₄(s)
planet → h₅(s)

h₂(t) → c₂ → h₃(t)

the planet man
...

w₂: know
Attention

know → h

ARG0 → h

I → h

ARG1 → h

planet → h

w2: know

... the planet man
Attention

The diagram illustrates an attention mechanism in a neural network, focusing on the words "know" and "planet". The network processes these words through hidden layers, labeled as $h_2(t)$, $c_2$, and $h_3(t)$. The output is then used to compute the attention weights, denoted as $w_2$, indicating how much each word contributes to the final output.

The text snippet overlaid on the diagram is:

```
I know the planet a lazy man inhabits
```

This sentence is highlighted to show how the attention mechanism prioritizes the words "planet" and "lazy" in the context of the sentence.
I know the planet a lazy man inhabits

<s>
know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy

I know the planet a lazy man inhabits</s>
Attention

- **know**
- **ARG0**
- **I**
- **ARG1**
- **planet**

The planet man...

I know the planet...

<\text{s}>
I know the planet a lazy man inhabits</\text{s>}

<table>
<thead>
<tr>
<th>know</th>
<th>ARG0</th>
<th>I</th>
<th>ARG1</th>
<th>planet</th>
<th>ARG1-of</th>
<th>inhabit</th>
<th>ARG0</th>
<th>man</th>
<th>mod</th>
<th>lazy</th>
</tr>
</thead>
</table>
Attention

know ARG0 I ARG1 planet ARG1-of inhabit ARG0 man mod lazy

know the planet a lazy man inhabits

The diagram illustrates the attention mechanism in a neural network, showing how different parts of the input are attended to and how they contribute to the output. The attention weights are visualized in the table below the diagram.
Issues to Address

Max-probability search
Issues to Address

Max-probability search

Issues
- short / similar outputs
- no guarantee that input is covered

I know a planet . </s>
I know the planet . </s>
I know the planet a </s>
I know the planet a lazy man . </s>
Issues to Address

Max-probability search

Issues
- short / similar outputs
- no guarantee that input is covered

Cheap Solutions
- Length penalty
- Coverage penalty (w/ attention weights)
Issues to Address
Issues to Address

Sparsity
Issues to Address

Sparsity
- Anonymize NE tokens
Issues to Address

**Sparsity**
- Anonymize NE tokens

President Obama stated that UK should keep …

person_name_0 stated that country_name_1 should keep …
Issues to Address

Sparsity
- Anonymize NE tokens
  - President Obama stated that UK should keep ...
  - person_name_0 stated that country_name_1 should keep ...
- Copy from input
Issues to Address

Sparsity
- Anonymize NE tokens

President Obama stated that UK should keep ...

person_name_0 stated that country_name_1 should keep ...

- Copy from input

```
I know the planet to inhabit man mod lazy

<s> I know the planet to inhabit man mod lazy</s>
```
Issues to Address

Sparsity
- Anonymize NE tokens

state ARG0 person_name_0 ARG1
keep ARG0 country_name_1 ...

President Obama stated that UK should keep ...

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- Copy from input
Issues to Address

Sparsity
- Anonymize NE tokens

President Obama stated that UK should keep ...

person_name_0 stated that country_name_1 should keep ...

- Copy from input

<s>know ARG0  l  ARG1 planet ARG1-of inhabit ARG0 man  mod  lazy</s>

<UNK>
Issues to Address

**Sparsity**
- Anonymize NE tokens

**President Obama** stated that **UK** should keep ...

**person_name_0** stated that **country_name_1** should keep ...

**Copy from input**

<table>
<thead>
<tr>
<th>input</th>
<th>output</th>
<th>prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>inhabit</td>
<td><strong>inhabits</strong></td>
<td>0.6</td>
</tr>
<tr>
<td>inhabit</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>inhabiting</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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Issues to Address

Sparsity
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state ARG0 person_name_0 ARG1
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Issues to Address

Sparsity
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- Copy from input

- CCG Parsing
Issues to Address

Sparsity
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President Obama stated that UK should keep …

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- Copy from input

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</tr>
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</tr>
<tr>
<td>…</td>
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- CCG Parsing
Issues to Address

Sparsity
- Anonymize NE tokens

President Obama stated that UK should keep …

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</tr>
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<td></td>
<td></td>
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</table>

- CCG Parsing Data Augmentation
Open Questions
Open Questions

Representations
- Probably shouldn’t treat all inputs as strings...
Open Questions

Representations
- Probably shouldn’t treat all inputs as strings…

Document Plans
- Maybe shouldn’t treat output as stream of strings…
Open Questions

Representations
- Probably shouldn’t treat all inputs as strings…

Document Plans
- Maybe shouldn’t treat output as stream of strings…

Optimize on some goal / Creative evaluation
- Don’t want just good-looking string of [X_language]…
Open Questions

Representations
- Probably shouldn’t treat all inputs as strings…

Document Plans
- Maybe shouldn’t treat output as stream of strings…

Optimize on some goal / Creative evaluation
- Don’t want just good-looking string of [X_language]…

Thank You