



Modern Natural Language Understanding and Generation

DR. SOTIRIOS CHATZIS, ASSISTANT PROFESSOR | CUT - FACULTY OF
ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING, COMPUTER ENGINEERING AND
INFORMATICS

Why Machine Learning?

- ▶ Computers and Internet provide easy access to data
- ▶ The amount of data is vast
- ▶ Modern AI is ML
- ▶ ML systems are founded upon statistical analysis arguments
- ▶ Potential to thrive in our data-rich world.

NLU & NLG concepts and tasks

3

- ▶ Natural Language Generation
 - ▶ An NLG system is able to ingest what is said to it, break it down, comprehend its meaning, and respond back in natural language
- ▶ Natural Language Understanding
 - ▶ NLU is actually a subset of NLG
- ▶ Question – Answering
 - ▶ Systems automatically answer questions posed by humans in natural language
- ▶ Summarization
 - ▶ Distilling the most important information from a document to produce a concise and fluent shorter version of that document while preserving key information content and overall meaning

Q&A Deep Neural Networks

4

Facts

John is in the playground.

John picked up the football.

Bob went to the kitchen.

Query

Where is the football?

Answer

playground

Q&A Deep Neural Networks

5

Task 1: Single Supporting Fact

Mary went to the bathroom.
John moved to the hallway.
Mary travelled to the office.
Where is Mary? **A:office**

Task 2: Two Supporting Facts

John is in the playground.
John picked up the football.
Bob went to the kitchen.
Where is the football? **A:playground**

Task 3: Three Supporting Facts

John picked up the apple.
John went to the office.
John went to the kitchen.
John dropped the apple.
Where was the apple before the kitchen? **A:office**

Task 4: Two Argument Relations

The office is north of the bedroom.
The bedroom is north of the bathroom.
The kitchen is west of the garden.
What is north of the bedroom? **A: office**
What is the bedroom north of? **A: bathroom**

Task 5: Three Argument Relations

Mary gave the cake to Fred.
Fred gave the cake to Bill.
Jeff was given the milk by Bill.
Who gave the cake to Fred? **A: Mary**
Who did Fred give the cake to? **A: Bill**

Task 6: Yes/No Questions

John moved to the playground.
Daniel went to the bathroom.
John went back to the hallway.
Is John in the playground? **A:no**
Is Daniel in the bathroom? **A:yes**

Task 7: Counting

Daniel picked up the football.
Daniel dropped the football.
Daniel got the milk.
Daniel took the apple.
How many objects is Daniel holding? **A: two**

Task 8: Lists/Sets

Daniel picks up the football.
Daniel drops the newspaper.
Daniel picks up the milk.
John took the apple.
What is Daniel holding? **milk, football**

Task 9: Simple Negation

Sandra travelled to the office.
Fred is no longer in the office.
Is Fred in the office? **A:no**
Is Sandra in the office? **A:yes**

Task 10: Indefinite Knowledge

John is either in the classroom or the playground.
Sandra is in the garden.
Is John in the classroom? **A:maybe**
Is John in the office? **A:no**

Q&A Deep Neural Networks

6

Task 11: Basic Coreference

Daniel was in the kitchen.
Then he went to the studio.
Sandra was in the office.
Where is Daniel? A: studio

Task 12: Conjunction

Mary and Jeff went to the kitchen.
Then Jeff went to the park.
Where is Mary? A: kitchen
Where is Jeff? A: park

Task 13: Compound Coreference

Daniel and Sandra journeyed to the office.
Then they went to the garden.
Sandra and John travelled to the kitchen.
After that they moved to the hallway.
Where is Daniel? A: garden

Task 14: Time Reasoning

In the afternoon Julie went to the park.
Yesterday Julie was at school.
Julie went to the cinema this evening.
Where did Julie go after the park? A: cinema
Where was Julie before the park? A: school

Task 15: Basic Deduction

Sheep are afraid of wolves.
Cats are afraid of dogs.
Mice are afraid of cats.
Gertrude is a sheep.
What is Gertrude afraid of? A: wolves

Task 16: Basic Induction

Lily is a swan.
Lily is white.
Bernhard is green.
Greg is a swan.
What color is Greg? A: white

Task 17: Positional Reasoning

The triangle is to the right of the blue square.
The red square is on top of the blue square.
The red sphere is to the right of the blue square.
Is the red sphere to the right of the blue square? A: yes
Is the red square to the left of the triangle? A: yes

Task 18: Size Reasoning

The football fits in the suitcase.
The suitcase fits in the cupboard.
The box is smaller than the football.
Will the box fit in the suitcase? A: yes
Will the cupboard fit in the box? A: no

Task 19: Path Finding

The kitchen is north of the hallway.
The bathroom is west of the bedroom.
The den is east of the hallway.
The office is south of the bedroom.
How do you go from den to kitchen? A: west, north
How do you go from office to bathroom? A: north, west

Task 20: Agent's Motivations

John is hungry.
John goes to the kitchen.
John grabbed the apple there.
Daniel is hungry.
Where does Daniel go? A: kitchen
Why did John go to the kitchen? A: hungry

Abstractive Summarization model

7

CNN/Daily Mail dataset

Original Text (truncated): lagos, nigeria (cnn) a day after winning nigeria's presidency, *muhammadu buhari* told cnn's christiane amanpour that **he plans to aggressively fight corruption that has long plagued nigeria** and go after the root of the nation's unrest. *buhari* said he'll "rapidly give attention" to curbing violence in the northeast part of nigeria, where the terrorist group boko haram operates. by cooperating with neighboring nations chad, cameroon and niger, **he said his administration is confident it will be able to thwart criminals** and others contributing to nigeria's instability. for the first time in nigeria's history, the opposition defeated the ruling party in democratic elections. *buhari* defeated incumbent goodluck jonathan by about 2 million votes, according to nigeria's independent national electoral commission. **the win comes after a long history of military rule, coups and botched attempts at democracy in africa's most populous nation.**

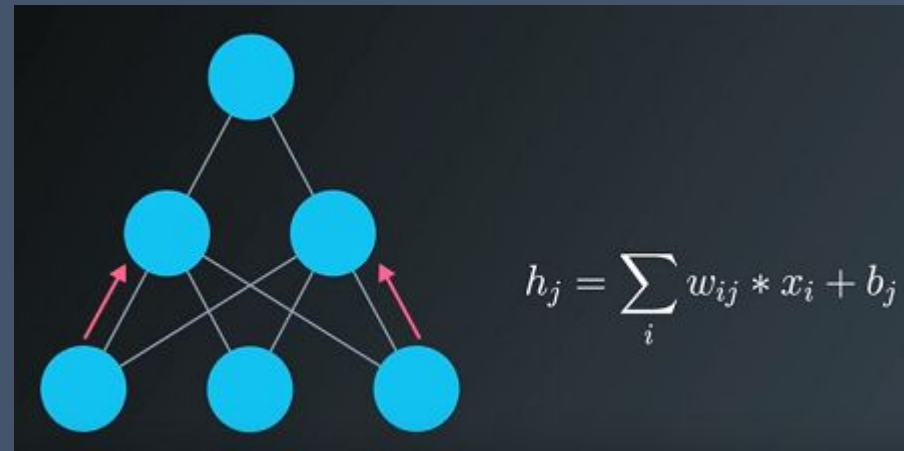
Pointer-Gen: *muhammadu buhari* says he plans to aggressively fight corruption **in the northeast part of nigeria**. he says he'll "rapidly give attention" to curbing violence **in the northeast part of nigeria**. he says his administration is confident it will be able to thwart criminals.

Pointer-Gen + Coverage: *muhammadu buhari* says he plans to aggressively fight corruption that has long plagued nigeria. he says his administration is confident it will be able to thwart criminals. the win comes after a long history of military rule, coups and botched attempts at democracy in africa's most populous nation.

Neural Network essentials

- ▶ Neurons or units
- ▶ Layers (input, hidden and output)
- ▶ Synaptic weight (connection between units)
 - ▶ Encode the pattern (statistical regularities)
- ▶ Data are turned into numbers and fed to the input
- ▶ For each layer
 - ▶ Multiply the input by the weights
 - ▶ Add a bias
 - ▶ Apply activation function (non-linear)
 - ▶ Pass the output to the next layer

This process is called **Forward Propagation**



Supervised Training

9

Task of finding a function that best approximates the training data.

- ▶ Given the **input** and the **weights**, the model generates its **output** (prediction)
- ▶ **Loss function** computes the **error (loss)** represented by the **difference** between prediction and ground-truth
- ▶ **Back-propagation** informs each layer of the **network** about the **output error**
- ▶ **Optimization algorithm updates the network weights accordingly**

The process is repeated until the model cannot improve the error further.

Memory augmented networks (1)

- ▶ Simple deep networks cannot store facts in memory for future retrieval.
- ▶ Their memory span mimics the cortex, as opposed to episodic memory in animal brains.
- ▶ **Memory Neural Networks (2014 – Weston et. al.)**
 - ▶ **Basic limitation of MemNN**
 - ▶ Merely a **read** functionality
 - ▶ Need of strong supervision (labelled data along with supporting facts)

Memory augmented networks (2)

11

▶ **Neural Turing Machine (2014 - Graves et. al.)**

- ▶ External addressable memory with read and write functionality
- ▶ NTM is focused on sorting, copying and recalling of memory data

▶ **MemNN vs NTM**

- ▶ MemNN has only read head while NTM has read and write head
- ▶ NTM is able to learn any algorithm while MemNN is a Q&A model
- ▶ NTM is trained in an unsupervised fashion while MemNN needs strong supervision

Memory augmented networks (3)

12

- ▶ **End-to-End Memory Network (2015 - Sukhbaatar et. al.)**
 - ▶ Encoder – Decoder
 - ▶ Encoder
 - ▶ Converts the input sequence to stored memories
 - ▶ Decoder
 - ▶ Produces the output sequence based on the context of stored memories
 - ▶ External, content based, memory mechanism
 - ▶ **Attention** mechanism; it learns where the decoder should attend to.
 - ▶ **Attention is trained on its own; no need of human supervision.**
 - ▶ Key difference from **MemNN** where supporting facts are required.

- ▶ Takes all memories (from the encoder) into account.
- ▶ Assigns different importance weights to each memory for symbol generation

NA Variants

- ▶ Global and Local Attention (Luong et. al., 2015)
 - ▶ Global: All source memories are taken into account
 - ▶ Local: Limited subset (window) around a predicted position is used
- ▶ Joint-Attention mechanism (Luong et. al., 2018)
 - ▶ Summarization tasks
 - ▶ Addresses word or phrase repetition
 - ▶ Apart from input-wise attention (encoder), we also use output-wise (decoder)
 - ▶ Output-wise attention aim is to reduce repetitions

Q&A Deep Neural Networks

14

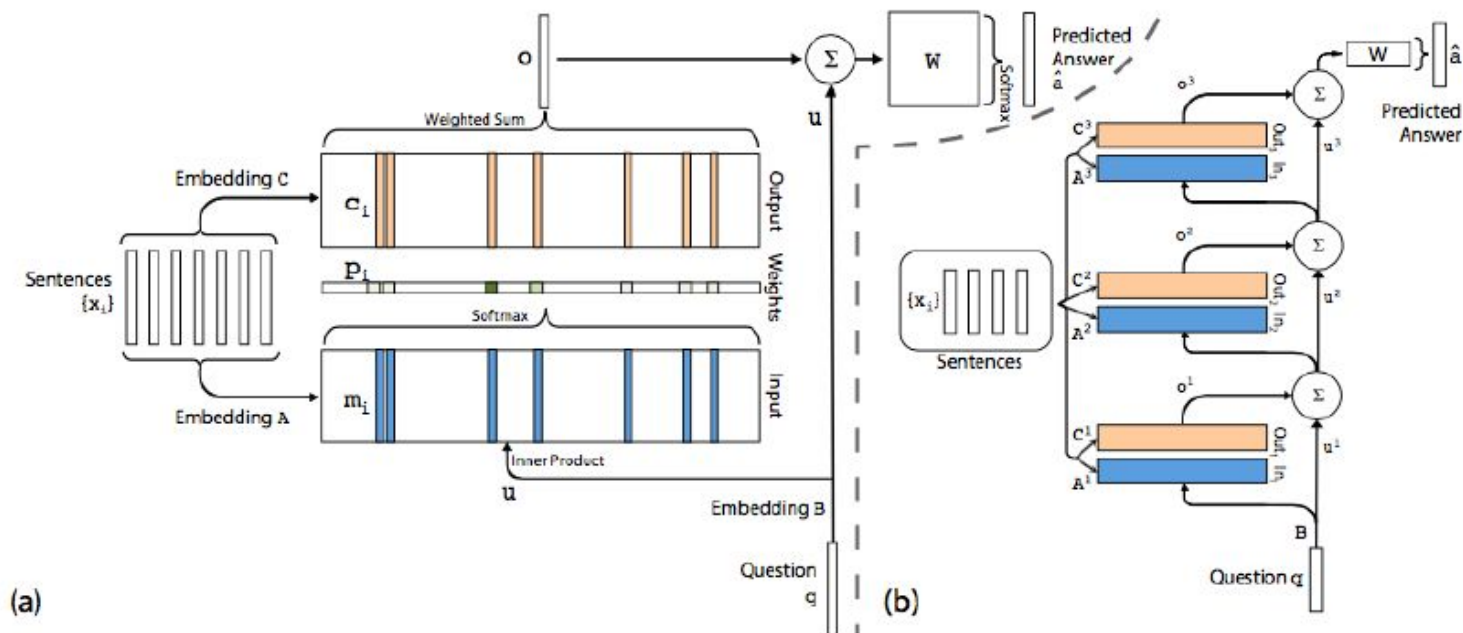


Figure : (a) A single-layer version of the considered model. (b) A 3-layer version, obtained via stacking.

Document Summarization

15

Summarization is the process of creating a shorter version of the original text, preserving the most salient information, without altering the basic concepts.

Extractive Summarization

- ▶ Simply **select** some sentences or words to **copy** from the original text

Abstractive Summarization

- ▶ **Generation** of text during the summarization process

Abstractive Summarization challenges:

- ▶ Coping with OOV words
- ▶ Grammar and syntax
- ▶ Detecting salient information
- ▶ Repetitions