

Controllable Text Generation

Should machines reflect the way humans interact in society?

Shrimai Prabhumoye



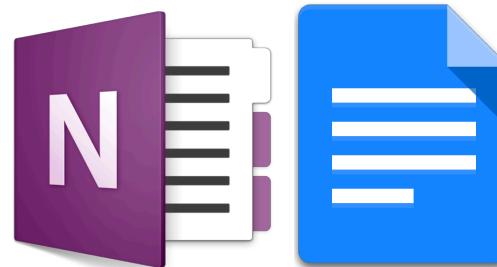
Carnegie Mellon University
Language Technologies Institute

We constantly author text!

Style, Content and Structure



Social Media



Personal/Professional documents



Blogs



News/Wiki articles

Style

- Expressed in the choice of *words or phrases* as well as *syntactic structures* used to convey information
- I define style as a group of natural language sentences that belong to a particular class or label.

“Do you have any code that we can look at?”

“Any code? Or do I have to guess at how you did it?”

(Danescu-Niculescu-Mizil, 2013)

Content

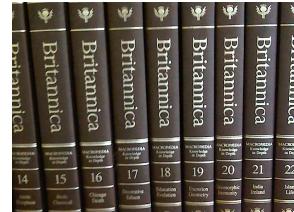
- Human communication by definition is a process by which individuals *exchange information* and influence one another through a common system of symbols and signs.
- Leverage information in the unstructured form



Wikipedia



Gutenberg



Encyclopedia



Internet

Content

Alice: The Notebook is hands-down one of my favorite movies EVER! Have you ever seen The Notebook?

Bob: No I have never seen this movie. I am going to try it out now

Alice: It was a heartwarming story of young love. The main characters are played by Ryan Gosling and Rachel McAdams.

Bob: Ok this sounds nice. I think Ryan is a good actor

Alice: For all the praise it received, I was surprised to see that it only got a 5.7/10 on Rotten Tomatoes.

Bob: That is interesting. They never get the rating correct.

Alice: The story goes back and forth between present day and the past. Older Ryan is played by James Garner and older Rachel is played by Gena Rowlands. Yeah, Rotten Tomatoes never gets the right ratings. I always like to see the ratings but if I want to see a movie, I will watch it even if it has a bad rating.

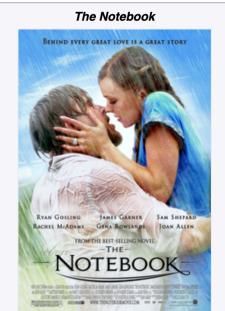
The Notebook

From Wikipedia, the free encyclopedia

For other uses, see *Notebook* (disambiguation).

The Notebook is a 2004 romantic drama film directed by Nick Cassavetes and written by Jeremy Leven from Jan Sardi's adaptation of the 1996 novel by Nicholas Sparks. The film stars Ryan Gosling and Rachel McAdams as a young couple who fall in love in the 1940s. Their story is narrated from the present day by an elderly man (played by James Garner), telling the tale to a fellow nursing home resident (played by Gena Rowlands, who is Cassavetes's mother).

The Notebook received generally mixed reviews, but performed well at the box office and received a number of award nominations, winning eight Teen Choice Awards, a Satellite Award, and an MTV Movie Award. The film became a sleeper hit^{[3][4]} and has gained a cult following.^{[5][6]} On November 11, 2012, ABC Family premiered an extended version with deleted scenes added back into the original storyline.^[7]



Theatrical release poster
Directed by
Nick Cassavetes

Reception [edit]

Box office [edit]

The film premiered June 25, 2004, in the United States and Canada and grossed \$13,464,745 in 2,303 theaters its opening weekend, ranking number 4 at the box office.^[33] The film grossed a total of \$115,603,229 worldwide, \$81,001,787 in Canada and the United States and \$34,601,442 in other countries.^[2] It is the 15th highest-grossing romantic drama film of all time.^[34]

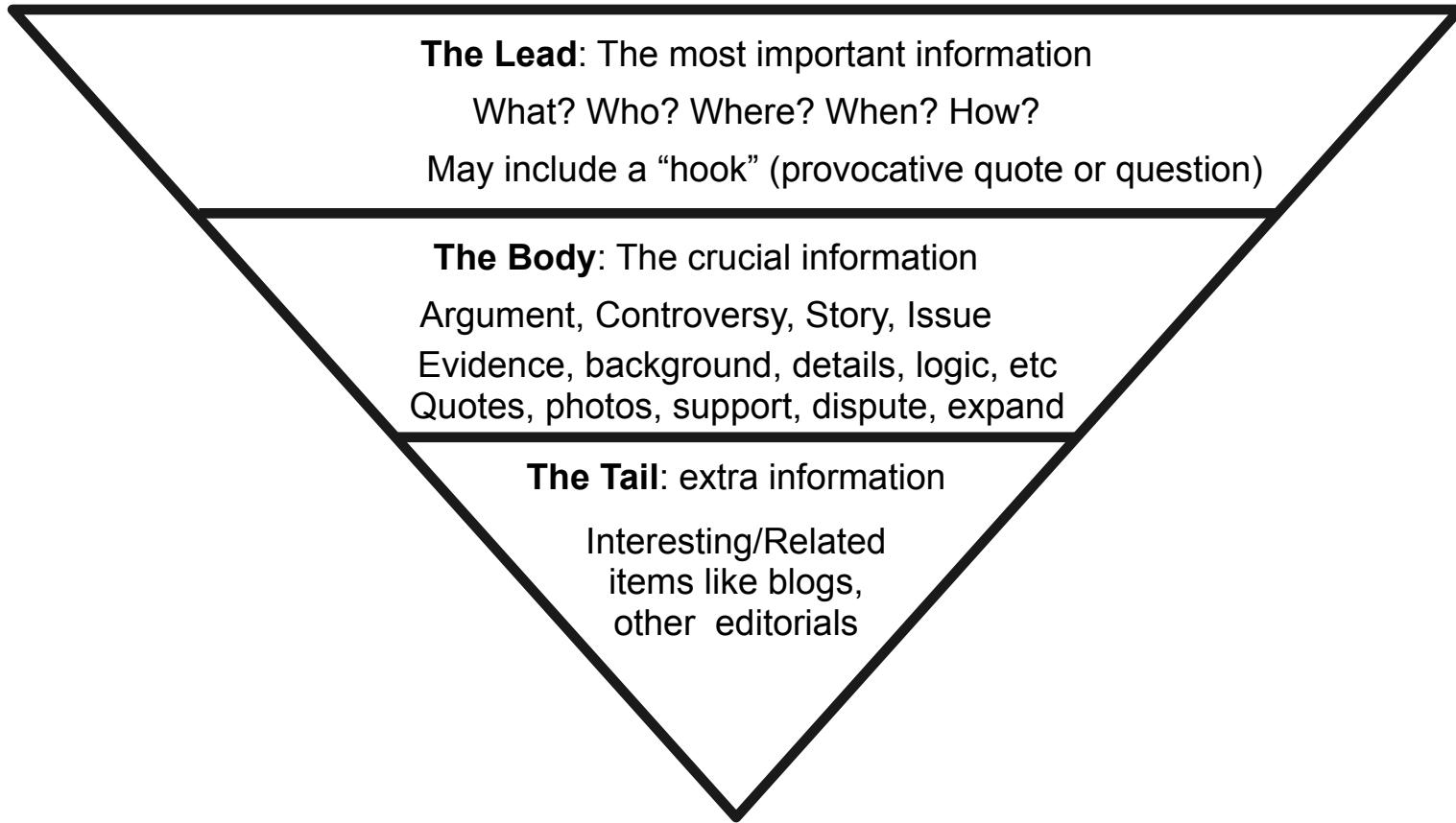
Critical reception [edit]

The Notebook received a mixed reaction from film critics. The 178 reviews on review aggregator Rotten Tomatoes show that 53% of critics gave the film a positive review, with an average rating of 5.64/10 and the website's consensus stating "It's hard not to admire its unabashed sentimentality, but *The Notebook* is too clumsily manipulative to rise above its melodramatic clichés."^[35] At Metacritic, which assigns an average rating out of 100 to reviews from mainstream critics, the film currently holds an average score of 53, based on 34 reviews, which indicates "mixed or average reviews."^[36]



The performances of Ryan Gosling and Rachel McAdams, as well as their on-screen chemistry, were particularly praised by most film critics

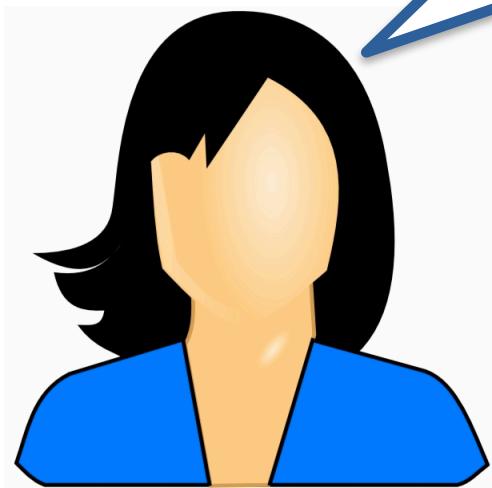
Structure



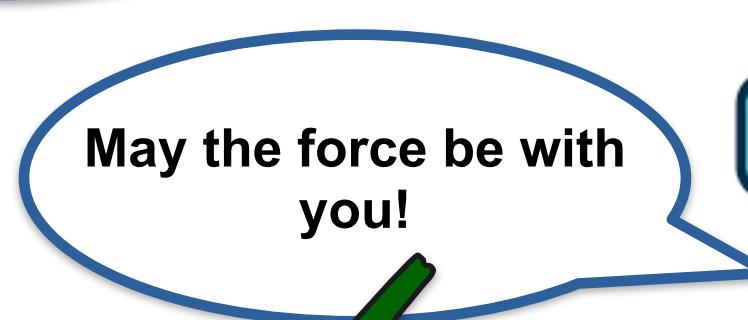
Application



Application



I have a talk to
present today!



May the force be with
you!

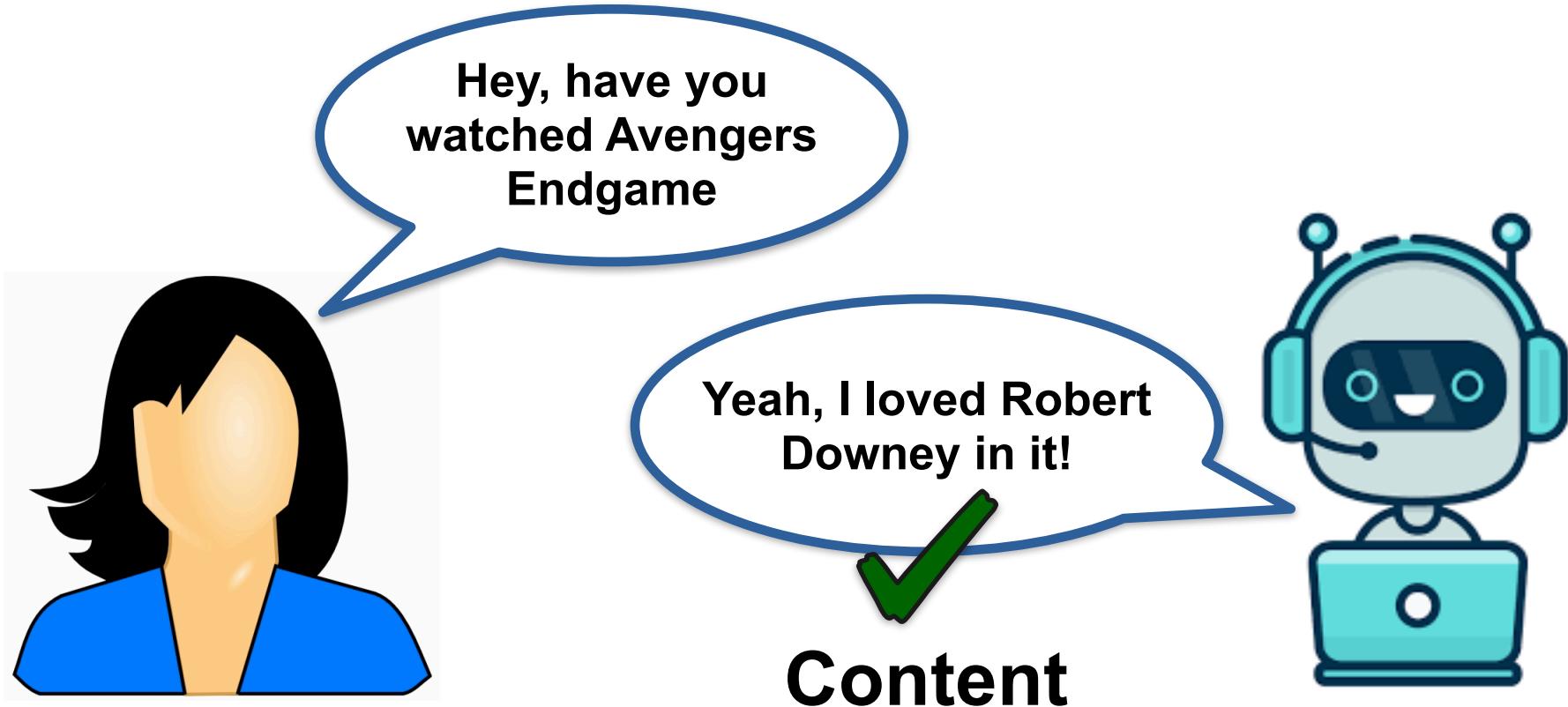


Style

Application



Application



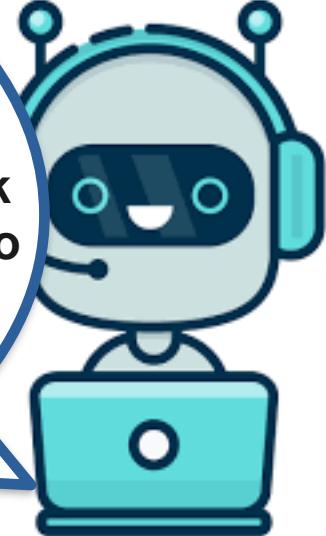
Application



Application



oh
great! Can you tell me
the story!

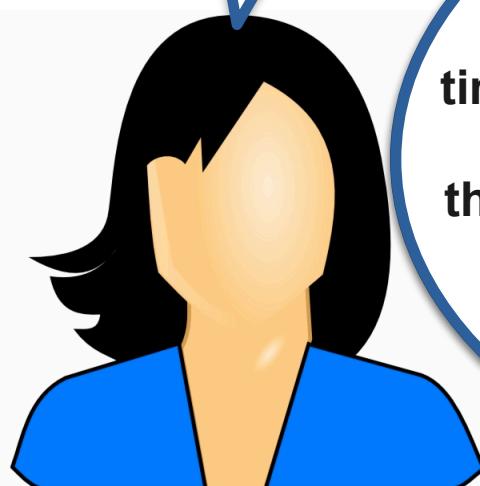


Yeah, Ironman steals the Infinity Stones back from Thanos and uses them to disintegrate Thanos and his army, at the cost of his life. Thor decapitates Thanos. Hulk travels to New York City in 2012 and convinces the Ancient One to give him the Time Stone. Five years later, AntMan escapes from the quantum realm. Ironman builds a time machine to save the world.



Structure

Application



oh
great! Can you tell me
the story!



Yeah, Thor decapitates Thanos. Five years later, AntMan escapes from the quantum realm. Ironman builds a time machine to save the world. Hulk travels to New York City in 2012 and convinces the Ancient One to give him the Time Stone. Ironman steals the Infinity Stones back from Thanos and uses them to disintegrate Thanos and his army, at the cost of his life.

Other Applications

- ***Writing Assistance Tools***
 - recommend formal language
 - recommend structural changes
- Recommend ***polite emails***
- ***Story Generation***
 - plot, ending, sentiment, topic, persona
- ***Content Generation*** (websites, descriptions etc)

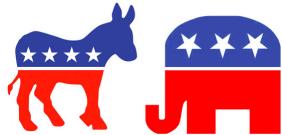
Overview

Controlled Generation Schema



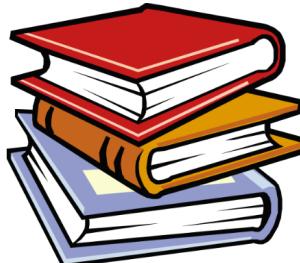
*draft
COLING '20*

Style



*draft ACL '20
Storytelling '19
ACL '18*

Content



*NAACL '19
EMNLP '18*

Structure



*draft ACL '20
draft ICML '20*

Ethical Considerations



WiNLP '19

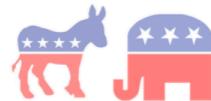
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***draft
COLING '20***

Style



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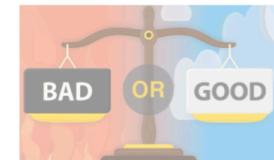
***NAACL '19
EMNLP '18***

Structure



***draft ACL '20
draft ICML '20***

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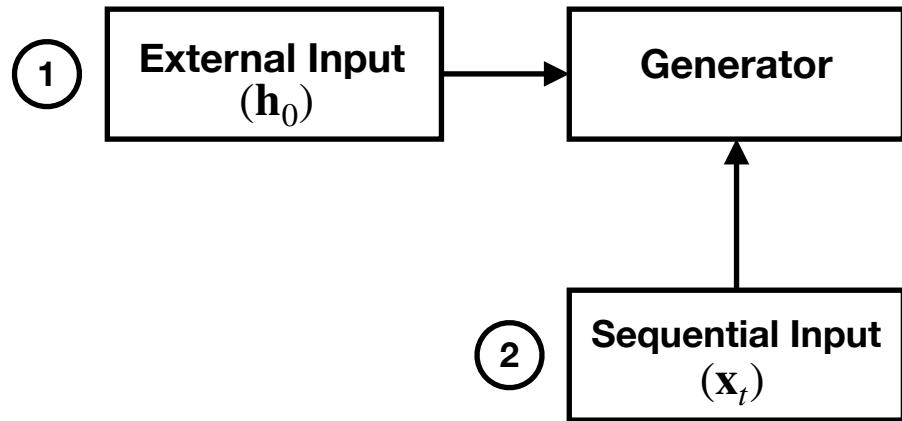
Goal

- ***Controlled Generation Schema*** connects prior work
 - Schema contains 5 modules
 - Identify any architecture as belonging to one of these modules
 - Schema can be used with any algorithmic paradigm
- ***Collate knowledge*** about different techniques
 - Insights into the advantages of techniques
 - Pave way for new architectures
 - Provide easy access to comparison

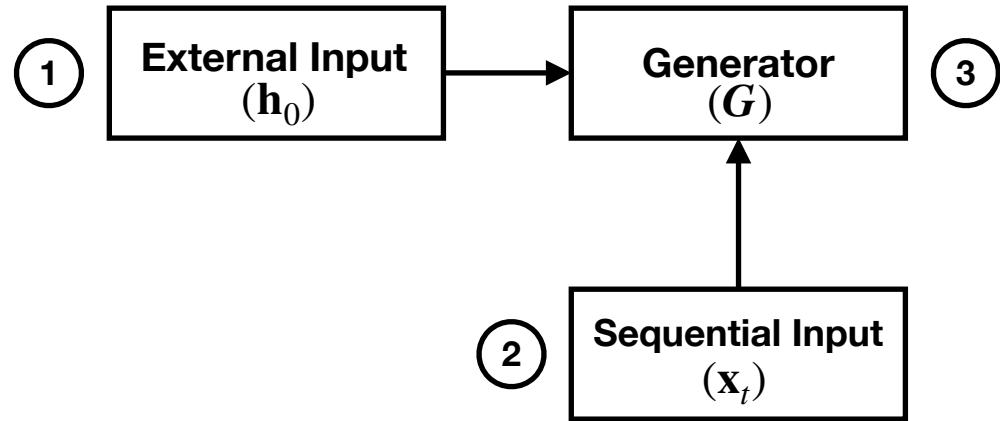
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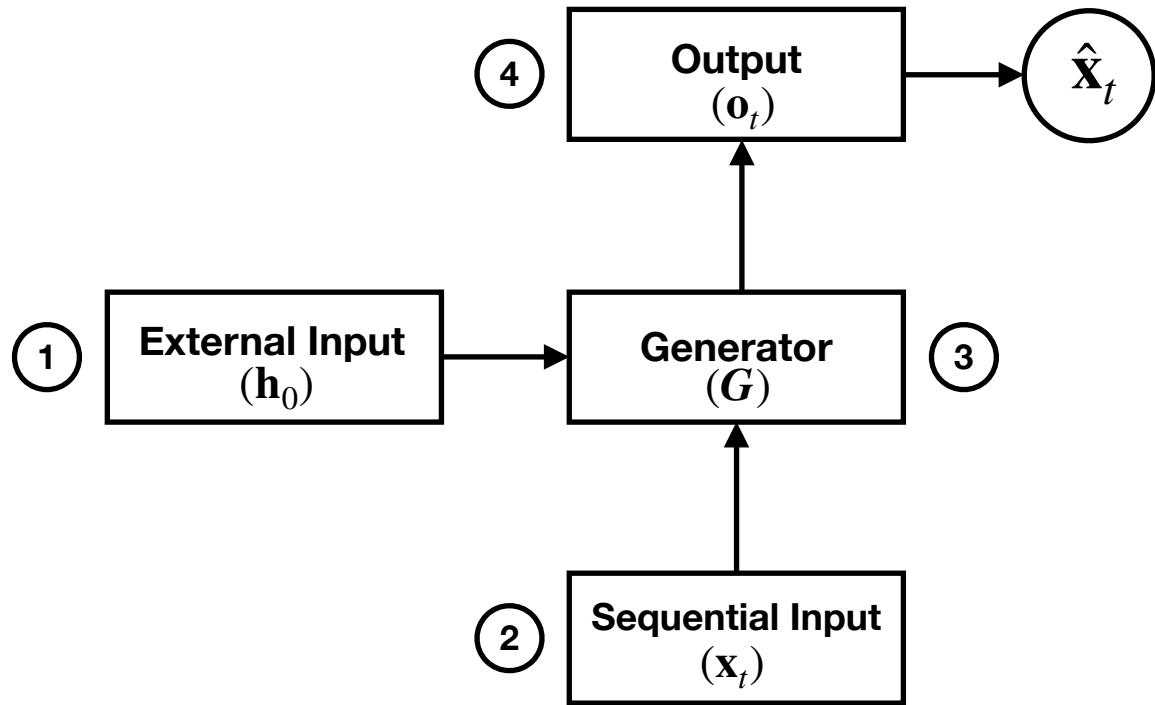
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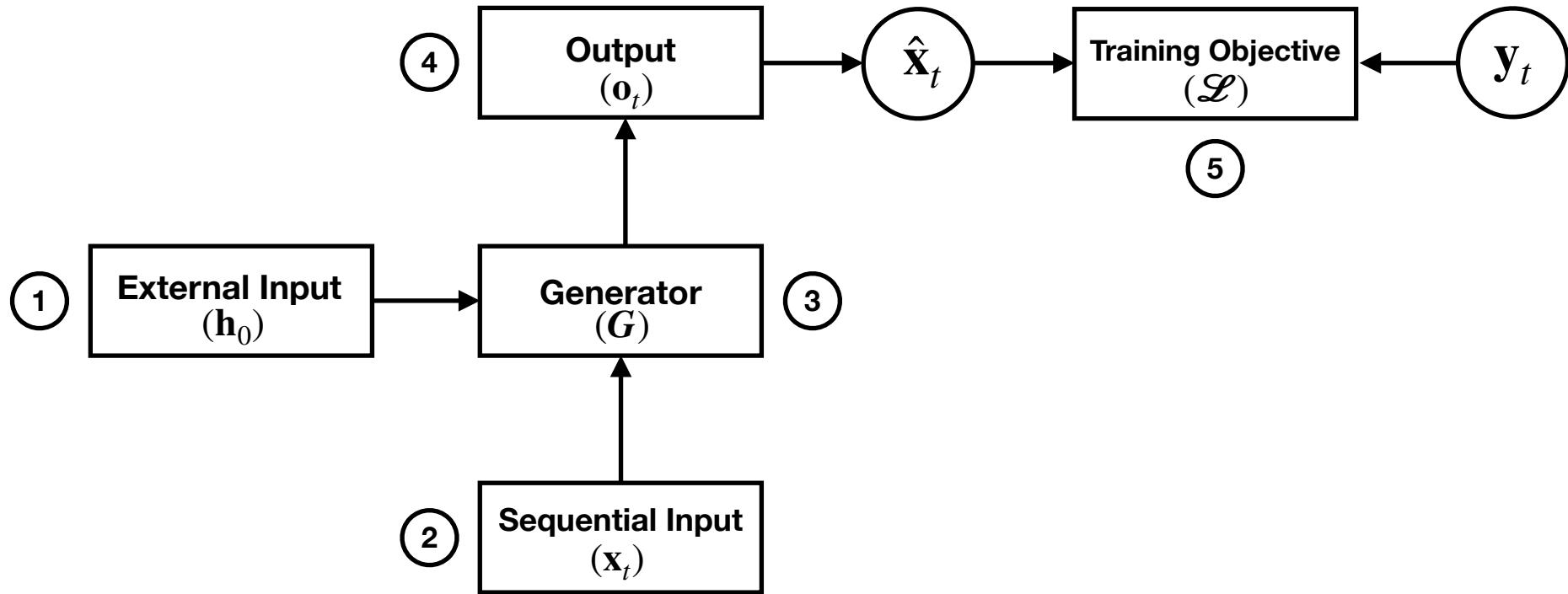
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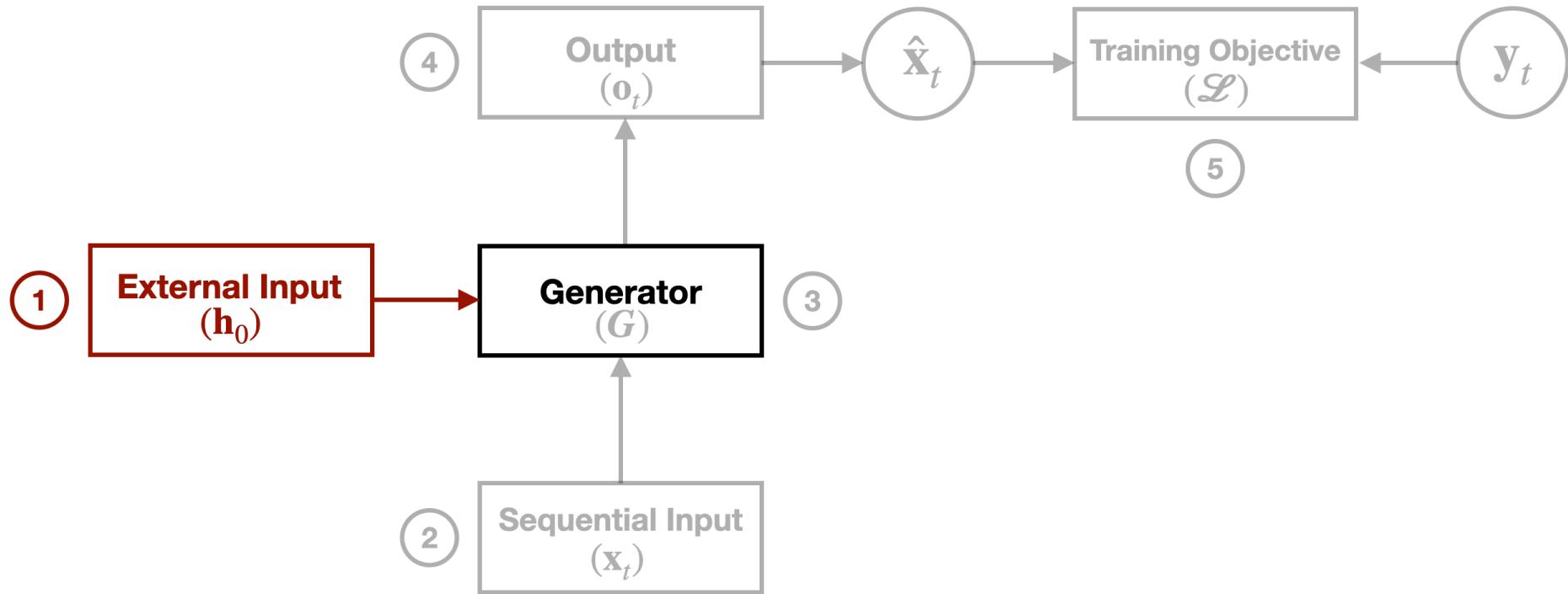
Controlled Generation Schema



Controlled Generation Schema

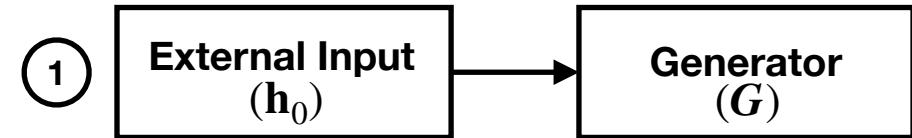


Controlled Generation Schema



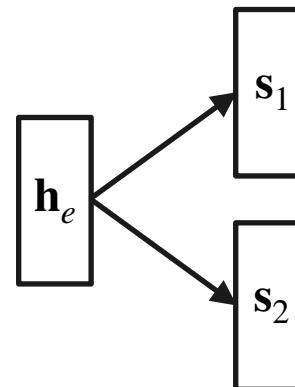
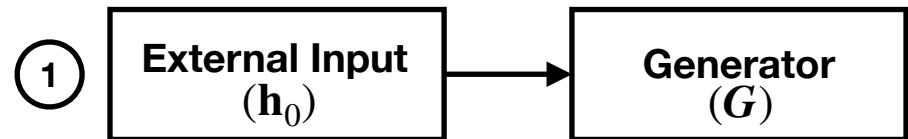
External Input

- \mathbf{h}_e = input sentence rep
- \mathbf{s} = control attribute rep
- Arithmetic or Linear Transform
 - $\mathbf{h}_0 = [\mathbf{h}_e; \mathbf{s}]$
 - $\mathbf{h}_0 = \mathbf{h}_e + \mathbf{s}$
 - $\mathbf{h}_0 = \tanh(\mathbf{W}_e \mathbf{h}_e + \mathbf{W}_s \mathbf{s} + \mathbf{b})$
- Decompose



External Input

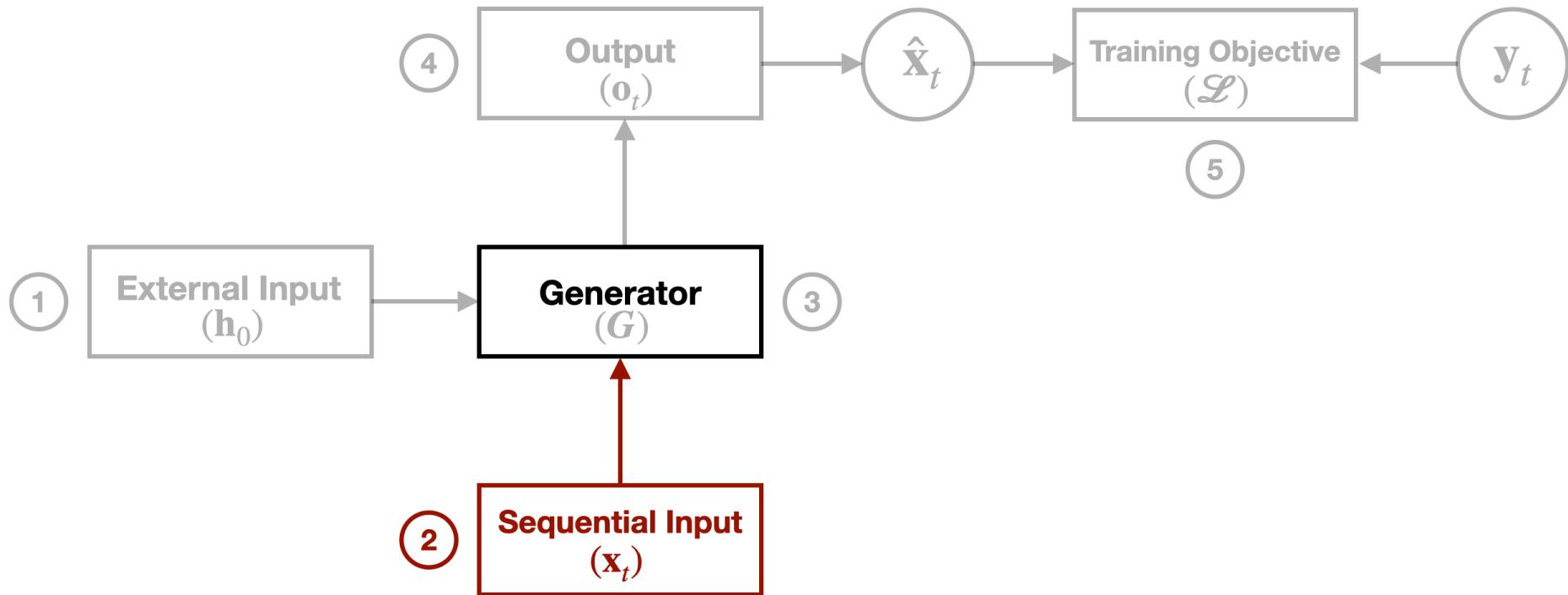
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Analysis

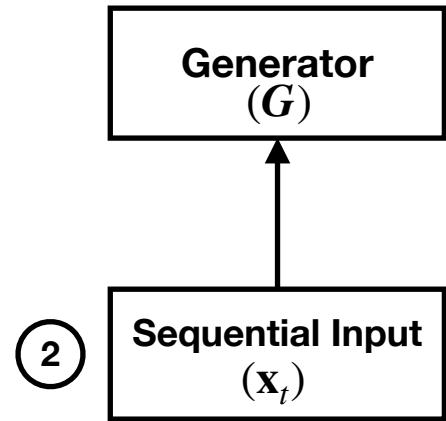
- **Arithmetic or Linear Transform**
 - Concatenating makes the model big
 - Adding loses information
 - Linear Transform might be better than above two
- **Decompose**
 - Provides *interpretable* representations
 - Input should contain signal of control attribute
 - Supervision on decomposed space

Controlled Generation Schema

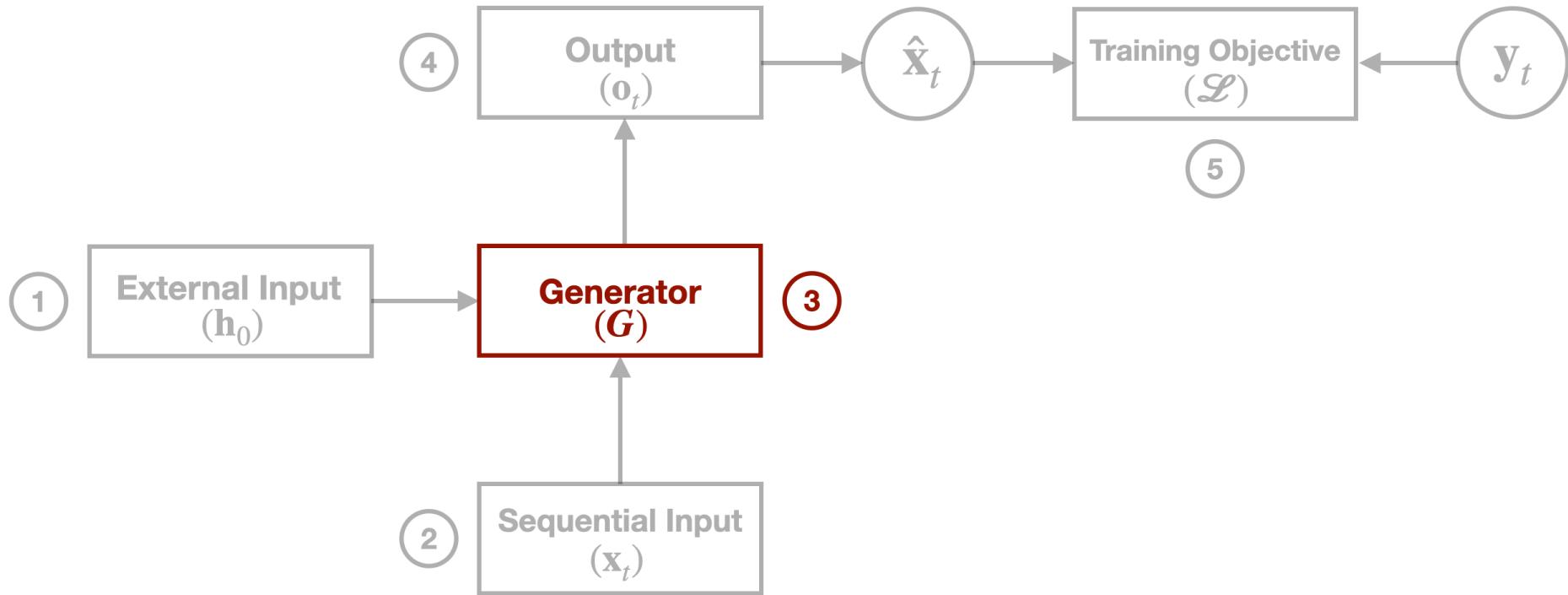


Sequential Input

- Arithmetic Changes
 - $\tilde{\mathbf{x}}_t = [\mathbf{x}_t; \mathbf{s}]$
 - $\tilde{\mathbf{x}}_t = \mathbf{x}_t + \mathbf{s}$
- Changes the input to the generation itself and not the context
- Not shown promising results so far



Controlled Generation Schema



Generator Operations

- **Controlled Generator Operations**

Generator
(G)

3

- $\mathbf{c}_t = \mathbf{f}_t \odot \mathbf{c}_{t-1} + \mathbf{i}_t \odot \tilde{\mathbf{c}}_t + \tanh(\mathbf{W}_d \mathbf{d}_t)$
 - \mathbf{d}_t = dialogue act representation, change made to LSTM cell
 - Add *dialogue act* information in the generation process
- $\tilde{\mathbf{h}}_t = \tanh(\mathbf{W}_h \mathbf{x}_t + \mathbf{r}_t \odot \mathbf{U}_h \mathbf{h}_{t-1} + \mathbf{s}_t \odot \mathbf{Yg} + \mathbf{q}_t \odot (\mathbf{1}_L^T \mathbf{Z} \mathbf{E}_t^{new})^T)$
 - \mathbf{s}_t = goal select gate; \mathbf{q}_t = item select gate, GRU cell
 - *recipe generation* task

Generator Operations

- **Controlled Generator Operations**

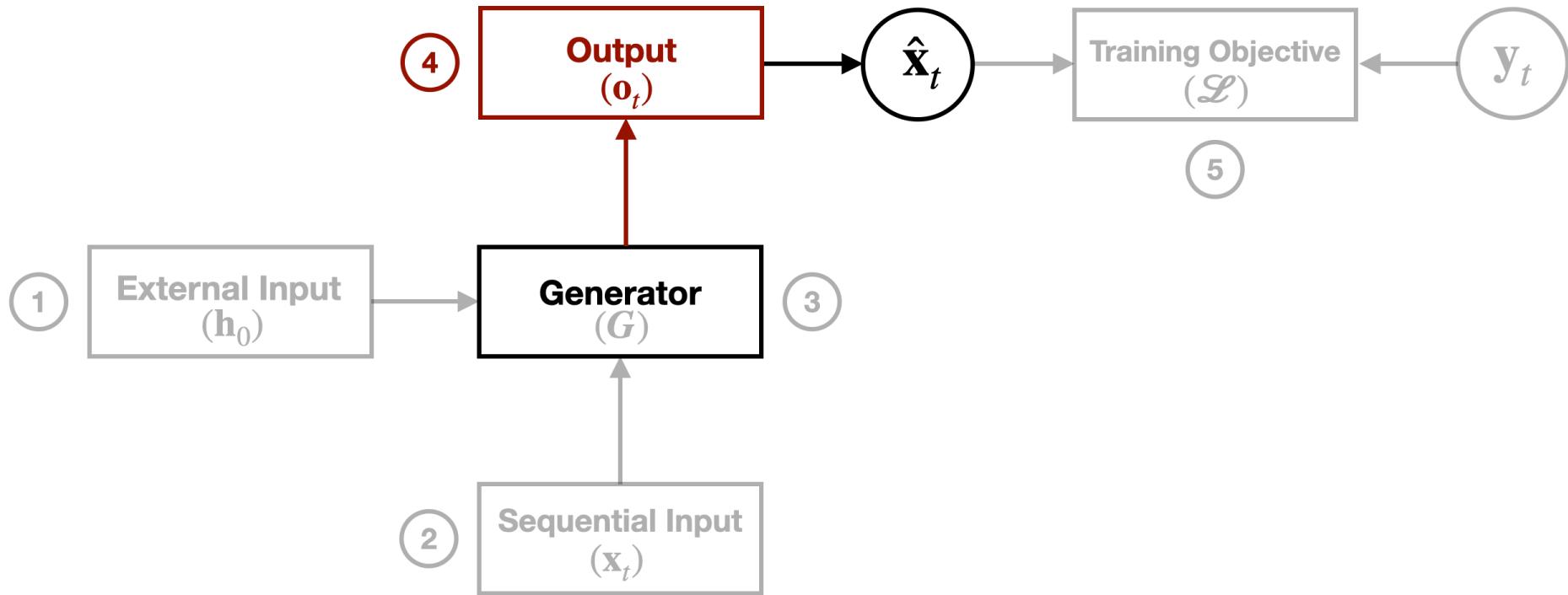
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Generator
(G)

3

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Controlled Generation Schema

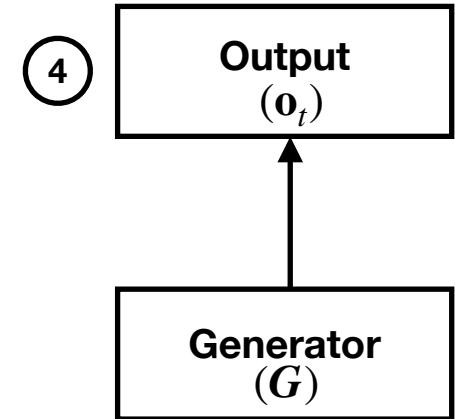


Output

- ***Attention***

- most effective - especially self and cross
- mostly control attribute tokens have been added to source sequence for attention
- under explored for controlling attributes but has a lot of potential

- ***External Feedback***



Output

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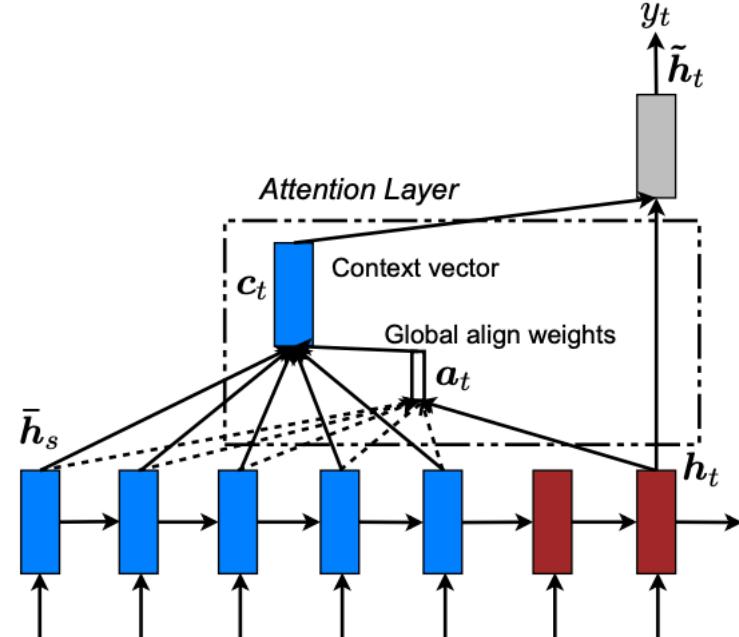


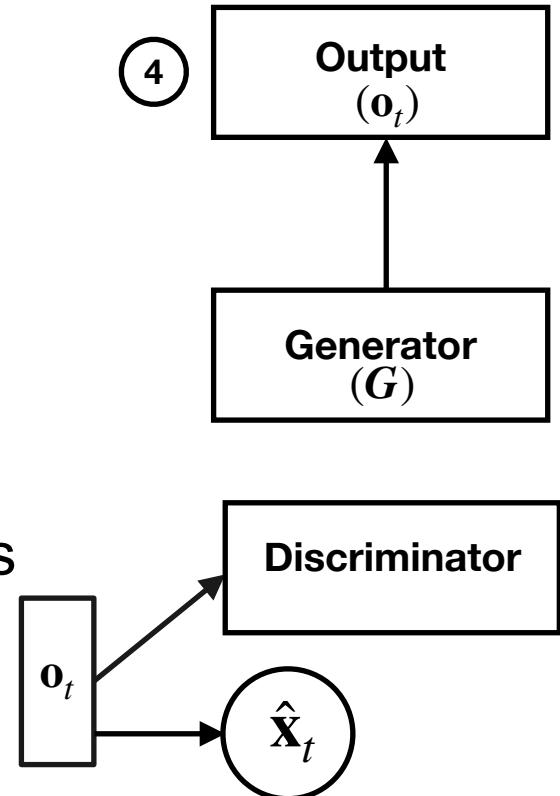
Figure 2: **Global attentional model** – at each time step t , the model infers a *variable-length* alignment weight vector a_t based on the current target state h_t and all source states \bar{h}_s . A global context vector c_t is then computed as the weighted average, according to a_t , over all the source states.

Output

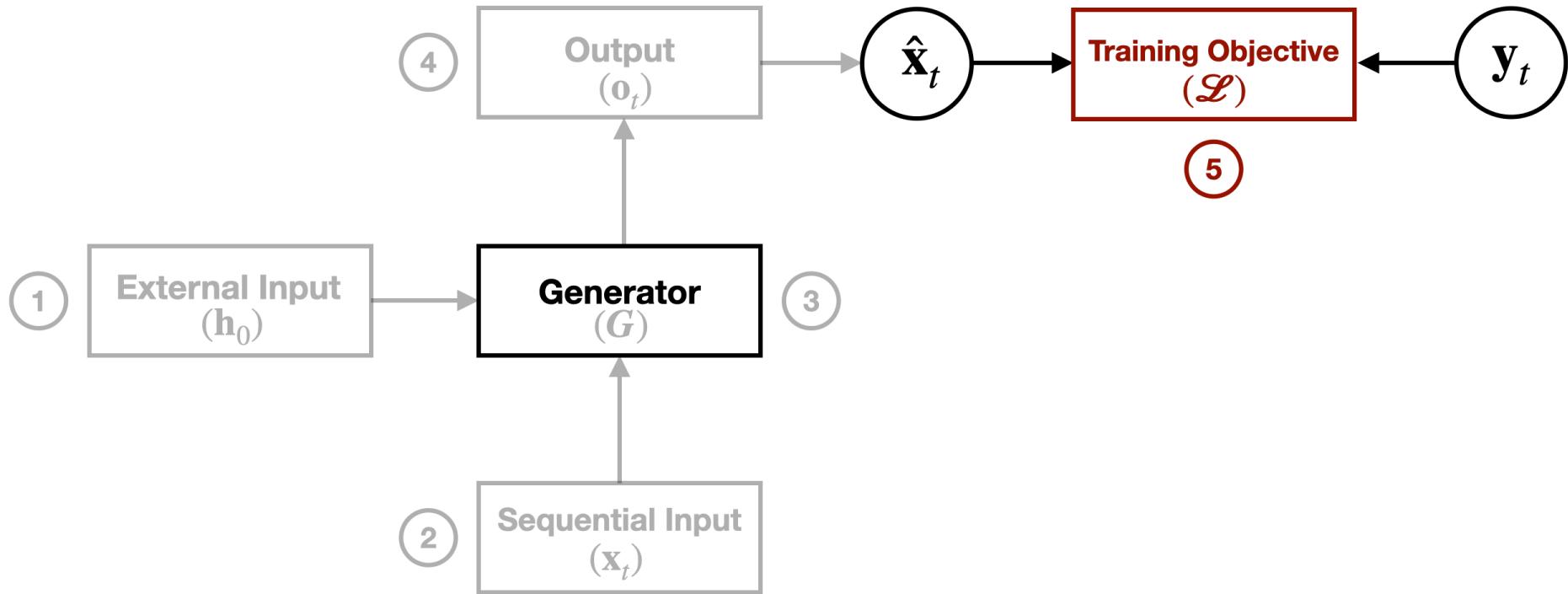
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Controlled Generation Schema



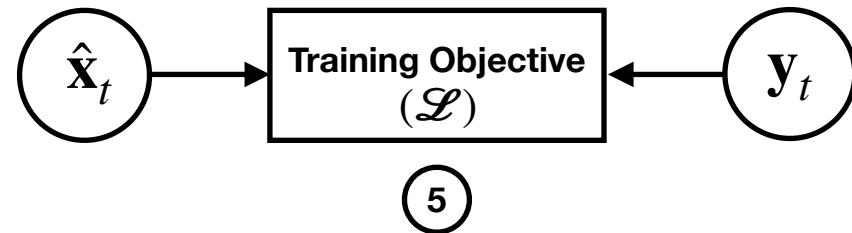
Training Objective

- ***General Loss***

- Cross Entropy Loss
- Unlikelihood Loss
- Decoding Strategies
- Used with any generation task

- ***Classifier Loss***

- design multiple classifier for any control attributes



Proposed Work

- ***Empirical Evaluation*** of the various technique described on 3 tasks
 - Style transfer
 - Content grounded generation
 - Persona grounded dialogue
- Gain insight into which techniques work better for what type of tasks

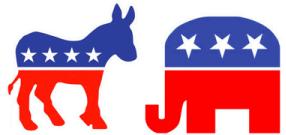
Overview

Controlled
Generation
Schema



draft ✓
COLING '20

Style



draft ACL '20
Storytelling '19
ACL '18

Content



NAACL '19
EMNLP '18

Structure



draft ACL '20
draft ICML '20

Ethical
Considerations



WiNLP '19

What is Style Transfer

- Rephrasing the text to contain specific stylistic properties without changing the intent or affect within the context.

“Shut up! the video is starting!”

“Please be quiet, the video will begin shortly.”

Challenges

- No Parallel Data!

“The movie was very long.”

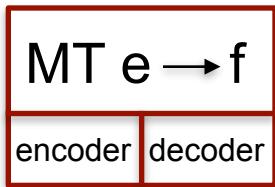
“I entered the theatre in the bloom of youth and emerged with a family of field mice living in my long, white mustache.”

- Disentangle content from style
- Style is subtle

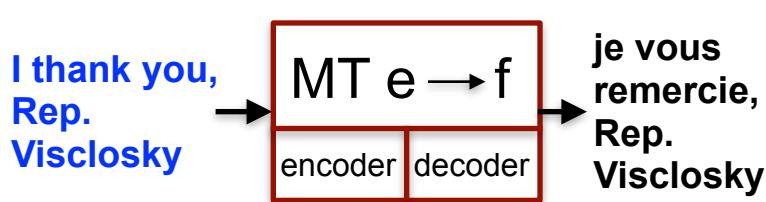
Our Solution

- ***Back-Translation***
 - Translating an English sentence to a pivot language and then back to English.
 - Reduces stylistic properties
 - Helps in grounding meaning
 - Creates a representation independent of the generative model
 - Representation is agnostic to the style task

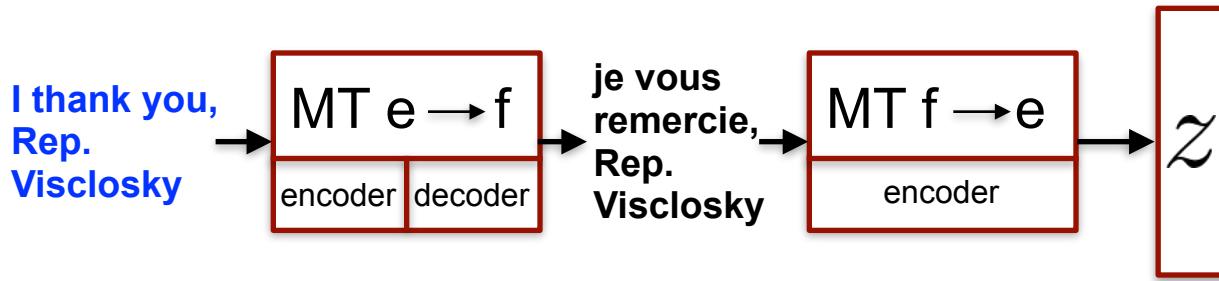
Architecture



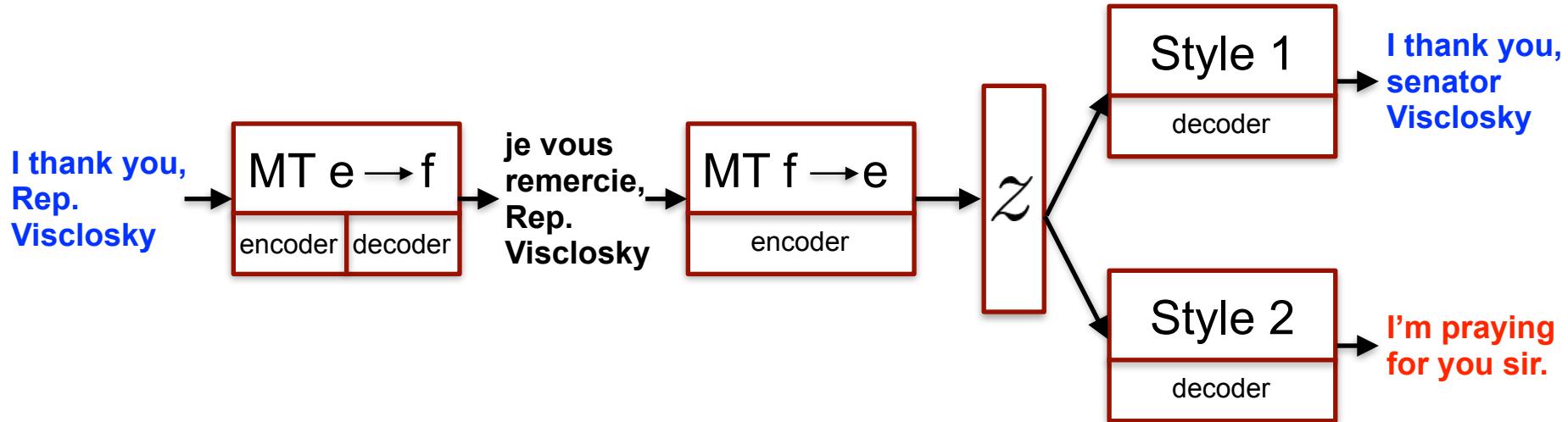
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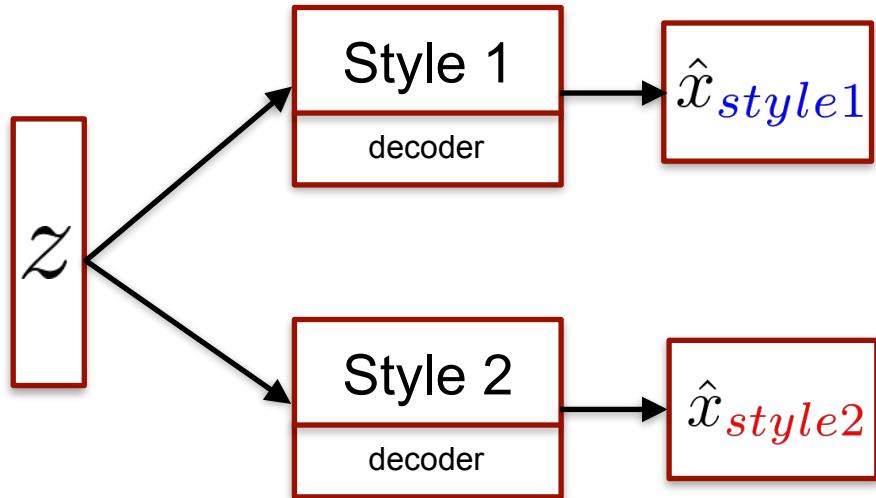
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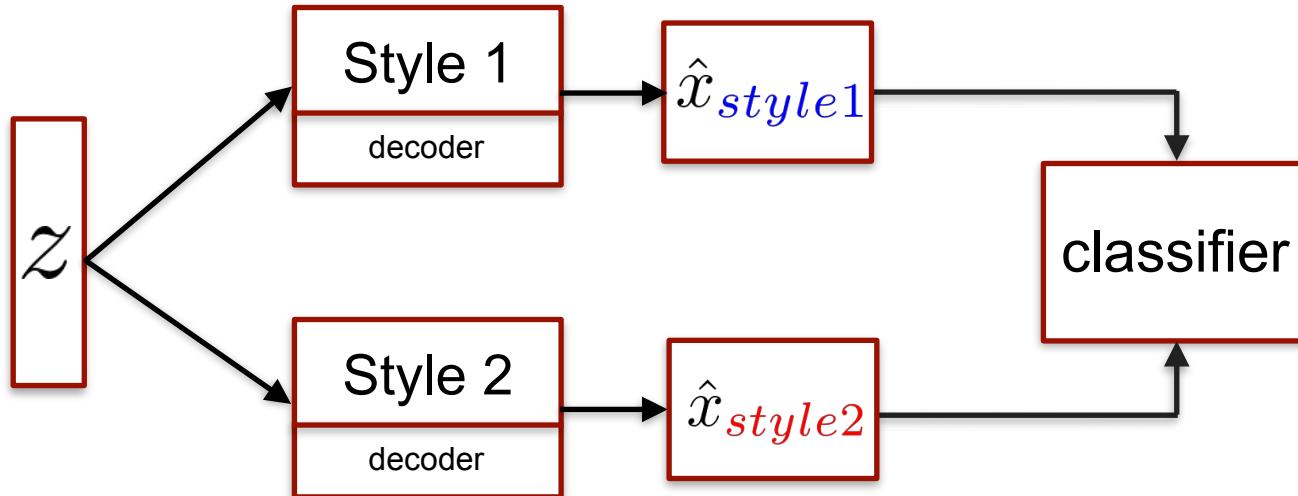
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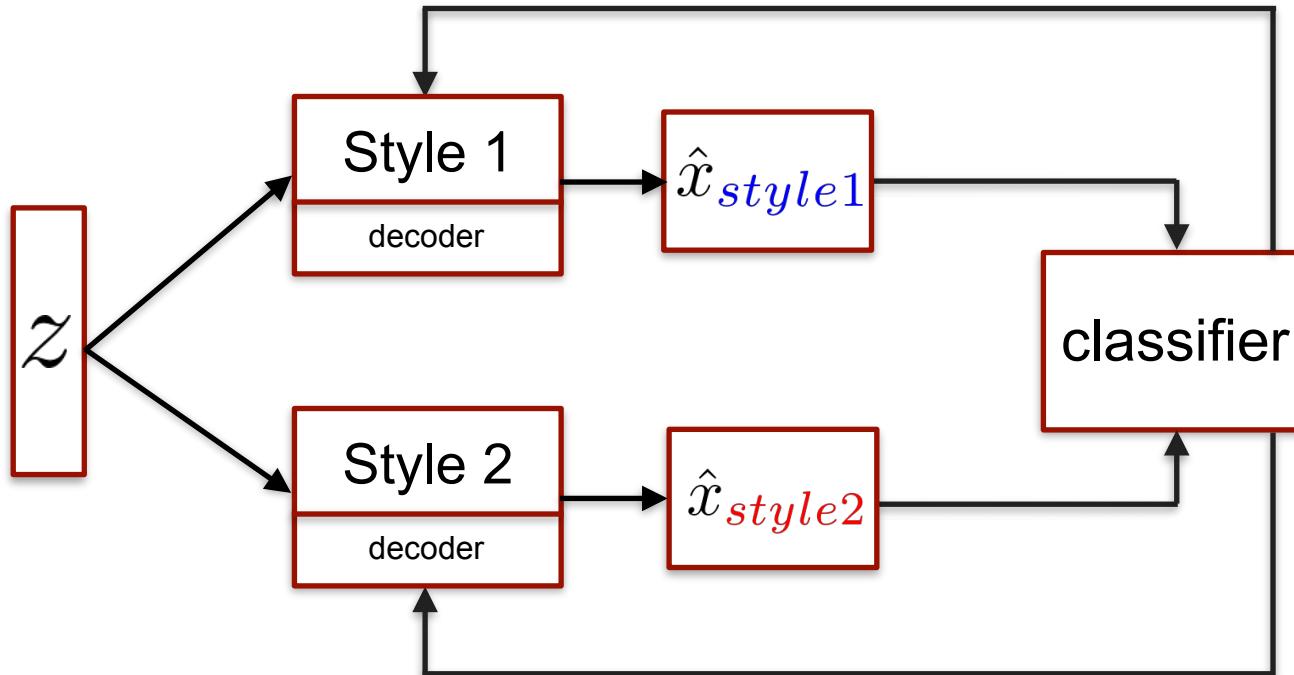
Train Pipeline



Train Pipeline



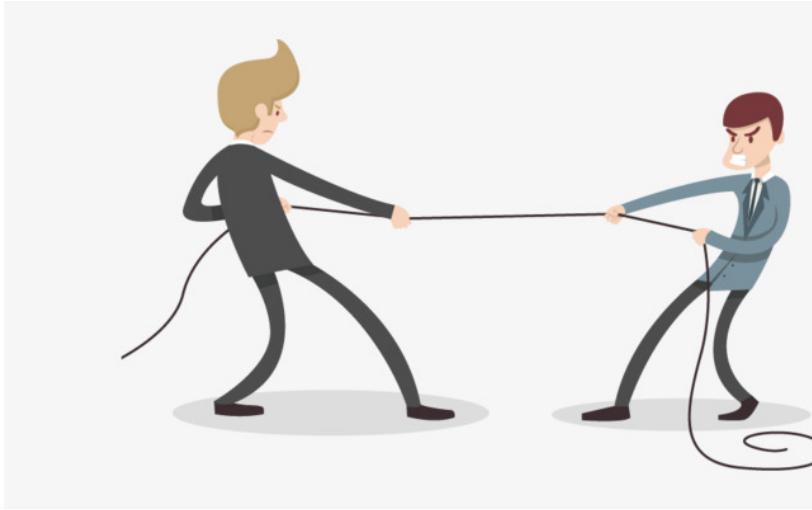
Train Pipeline



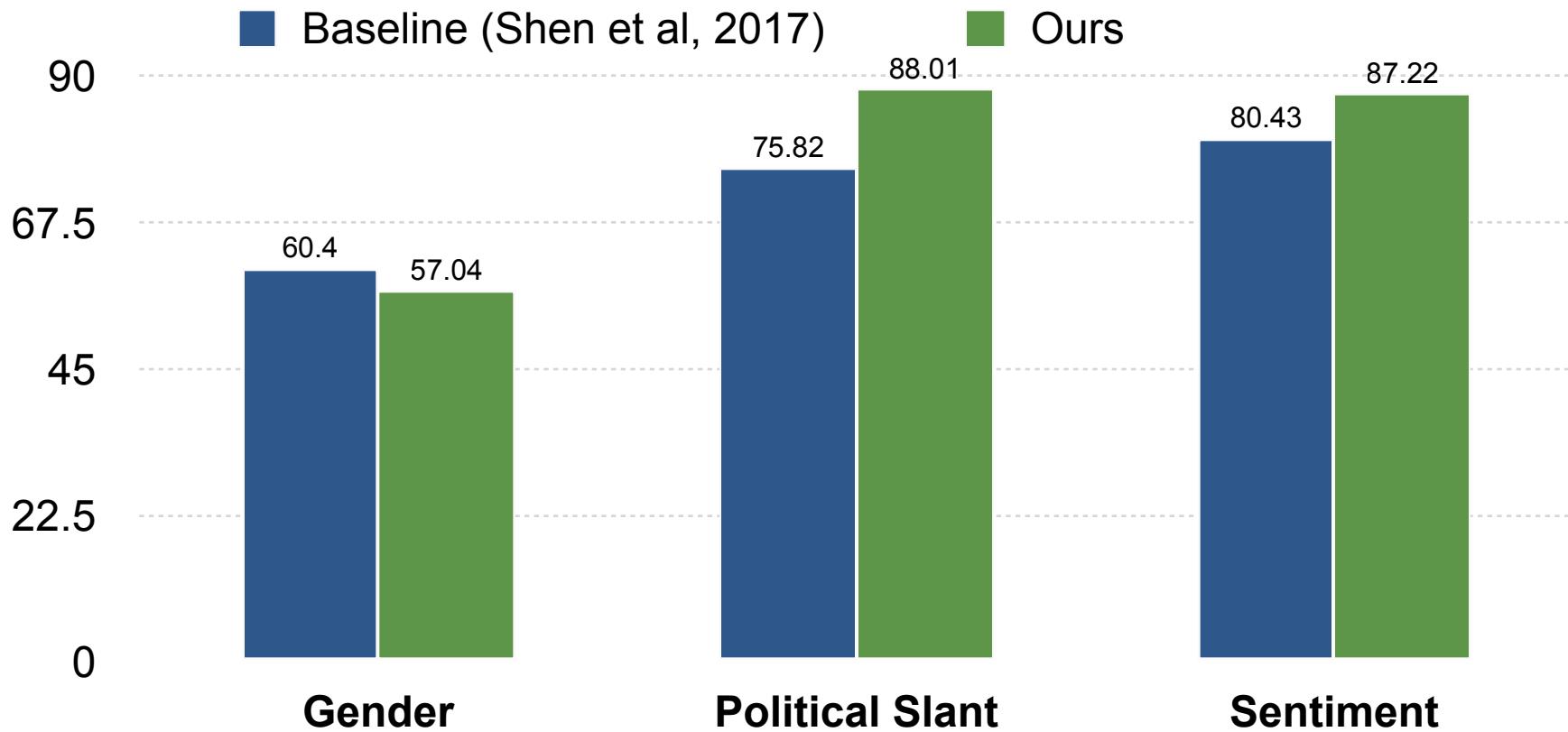
Experimental Settings

- Encoder-Decoders follow sequence-to-sequence framework (Sutskever et al., 2014; Bahdanau et al., 2015)

$$\min_{\theta_{\text{gen}}} \mathcal{L}_{\text{gen}} = \mathcal{L}_{\text{recon}} + \lambda_c \mathcal{L}_{\text{class}}$$



Style Transfer Accuracy



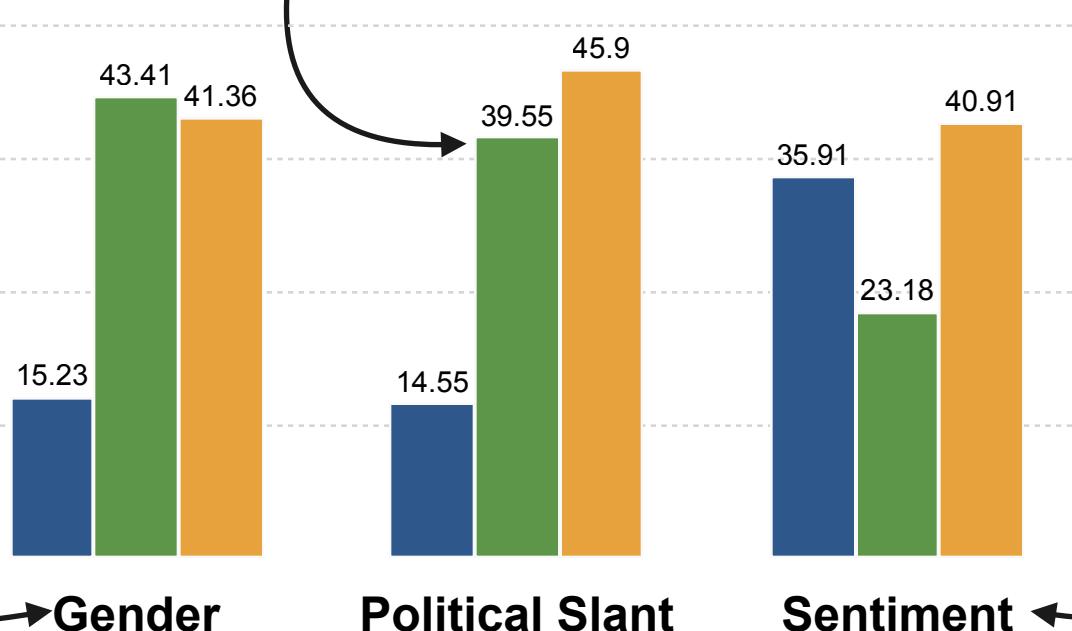
Preservation of Meaning

Which transferred sentence maintains the same sentiment of the source sentence in the same semantic context (i.e. you can ignore if food items are changed)

50
37.5
25
12.5
0

Which transferred sentence maintains the same semantic intent of the source sentence while changing the political position

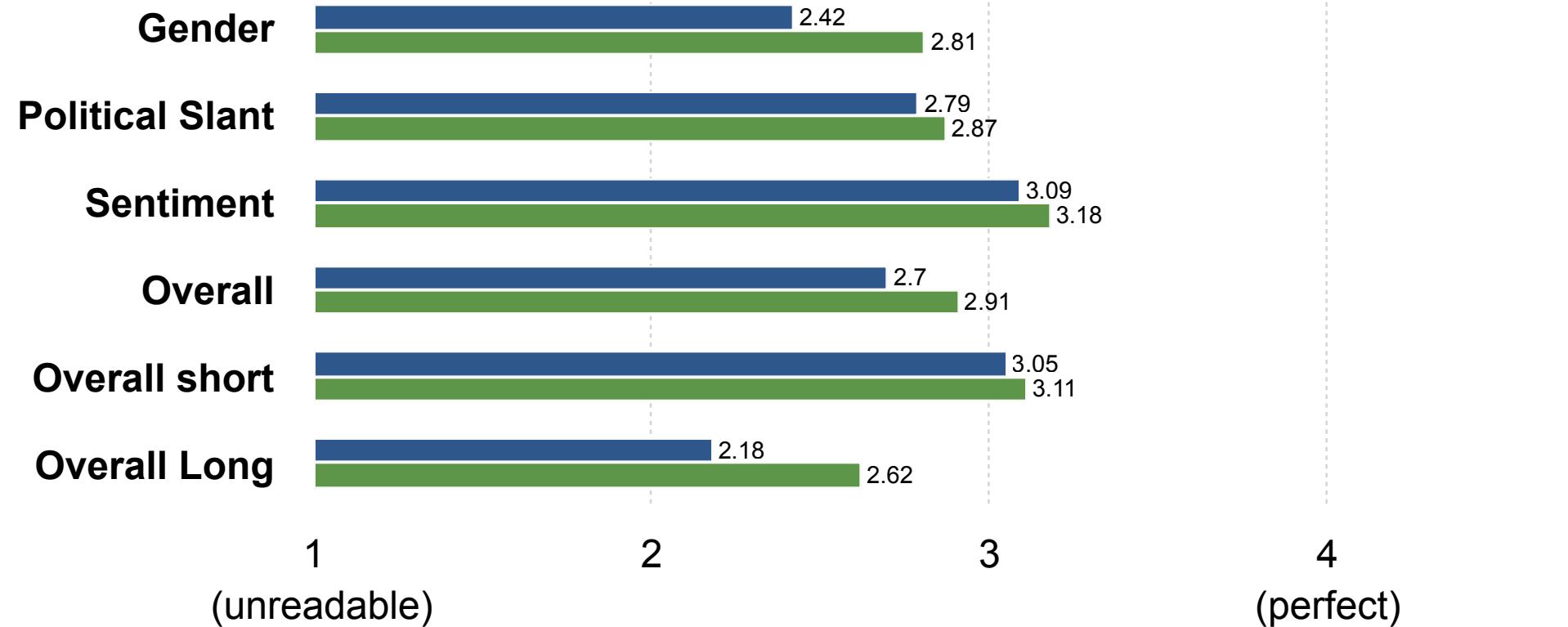
Baseline (Shen et al, 2017)
Ours
No Preference



Which transferred sentence is semantically equivalent to the source sentence with an opposite sentiment

Fluency

Baseline (Shen et al, 2017)
Ours



Proposed Work

- ***Style Representations***

- Cross domain tasks
 - Example: Generate stories in a particular persona
- Low Resource Setting
- Preserve Privacy
 - Distribute representation and not data

- ***Understanding Style***

- Formulate Transformations
- Better Style Transfer models

Style Representations

- *Average*

$$\mathbf{S}_{y_i} = \sum_{x_j \in y_i} BERT(x_j)$$

- **Task:** classifier to predict if two sentences belong to the same style or not (BERT-model)
 - Subtract *style representation* and predict (BERT-Style)
 - Subtract *random representation* and predict (BERT-Random)

Style Representations

- PASTEL dataset (Kang, 2019)
 - Gender, Age and Education

Model	Gender	Age	Education
BERT-model	56.10	58.42	58.94
BERT-Style	54.49	56.61	50.96
BERT-Random	54.98	58.10	58.94

Style Representation

- PASTEL dataset
- *Design techniques* to extract style
- *Evaluate* style representation
 - Style Transfer Task
 - Cross Domain
 - Gender with Yelp and PASTEL

Understanding Style

- *Ablation* studies on classifier
- ***Lexical Understanding***
 - N-gram features
 - distribution of function and content words
- ***Structural Understanding***
 - Parts of Speech N-grams
 - Parse Tree Features

Understanding Style

- PASTEL dataset
 - Gender: 3 classes, Age: 8 classes, Education: 9 classes
- ***POS-model***: SVM based on POS N-grams
- ***BERT-model***: numbers taken from (Kang, 2019)

Task	BERT-model	POS-model
Gender	73.0	71.7
Age	46.3	40.5
Education	42.5	38.0

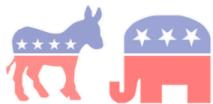
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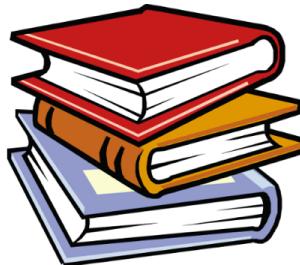
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Ethical Considerations



WiNLP '19

Content Transfer

After graduate form Columbia University, Obama worked in Chicago.

After graduating from Columbia University, Obama worked in Chicago.

After graduating from Carnegie Mellon University, Obama worked in Chicago.

After graduating from Columbia University, Obama worked in Chicago.

- AI assistance deals with *form* (grammar, style, etc.)
- Our goal is to control for *content*

What is our task?



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Background [edit]

On 4 July 2011 several publications including the *Daily Mail*,^{[8][10]} *The Telegraph*, and *The Guardian*^[11] picked up the story and published the pictures along with articles that quoted Slater as describing the photographs as self-portraits taken by the monkeys: "Monkey steals camera to snap himself" (*The Telegraph*),^[12] "a camera on a tripod" triggered by the monkeys (*The Guardian*),^[13] and a camera started by a monkey "Fascinated by her reflection in the lens".^[10] The articles also contained Slater quotes such as "He must have taken hundreds of pictures by the time I got my camera back." The following day, *Amateur Photographer* reported that Slater gave them further explanation as to how the photographs were created, downplaying the way newspaper articles had described them; Slater said reports that a monkey ran off with his camera and "began taking self-portraits" were incorrect and that the portrait was shot when his camera had been mounted on a tripod, with the primates playing around with a remote cable release as he fended off other monkeys.^[14]

spute



What is our task?



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On 4 July 2011 several publications including the *Daily Mail*,^[9] ^[10] *The Telegraph*, and *The Guardian*^[11] picked up the story and published the pictures along with articles that quoted Slater as describing the photographs as self-portraits taken by the monkeys: "Monkey steals camera to snap himself" (*The Telegraph*),^[12] "a camera on a tripod" triggered by the monkeys (*The Guardian*),^[13] and a camera started by a monkey "Fascinated by her reflection in the lens".^[10] The articles also contained Slater quotes such as "He must have taken hundreds of pictures by the time I got my camera back." The following day, *Amateur Photographer* reported that Slater gave them further explanation as to how the photographs were created, downplaying the way newspaper articles had described them;

Slater said reports that a monkey ran off with his camera and "began taking self-portraits" were incorrect and that the portrait was shot when his camera had been mounted on a tripod, with the primates playing around with a remote cable release as he fended off other monkeys.^[14]

spute



What is our task?



On 4 July 2011 several publications including the *Daily Mail*,^[9] *The Telegraph*,^[10] and *The Guardian*^[11] picked up the story and published the pictures along with articles that quoted Slater as

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The

Ape-rture priority photographer plays down monkey reports

Chris Cheesman July 5, 2011

A photographer who says he witnessed monkeys taking pictures of themselves, tells Amateur Photographer (AP) that much of the media coverage has been exaggerated.

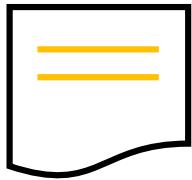
Wildlife photographer David Slater today played down newspaper reports that suggest a bunch of Indonesian monkeys grabbed his camera and began taking self-portraits.

Slater said reports that a monkey ran off with his camera and "began taking self-portraits" were incorrect and that the portrait was shot when his camera had been mounted on a tripod, with the primates playing around with a remote cable release as he fended off other monkeys.^[14]

spute

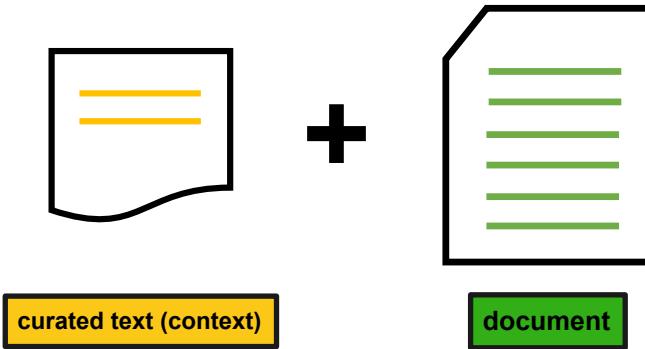


Primary Contribution

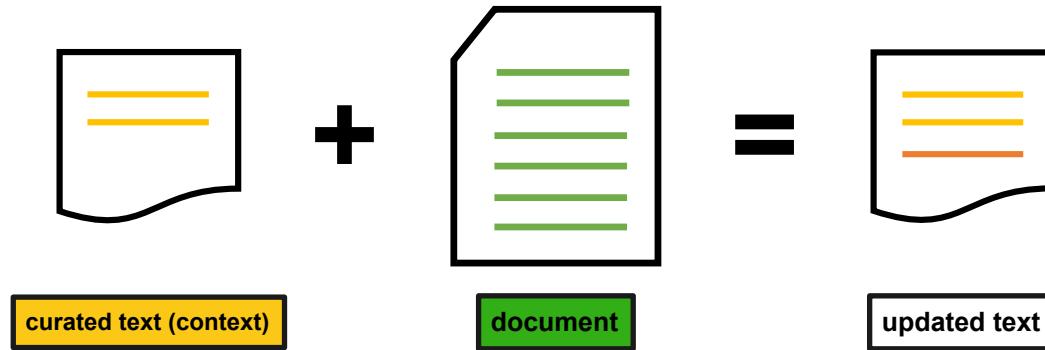


curated text (context)

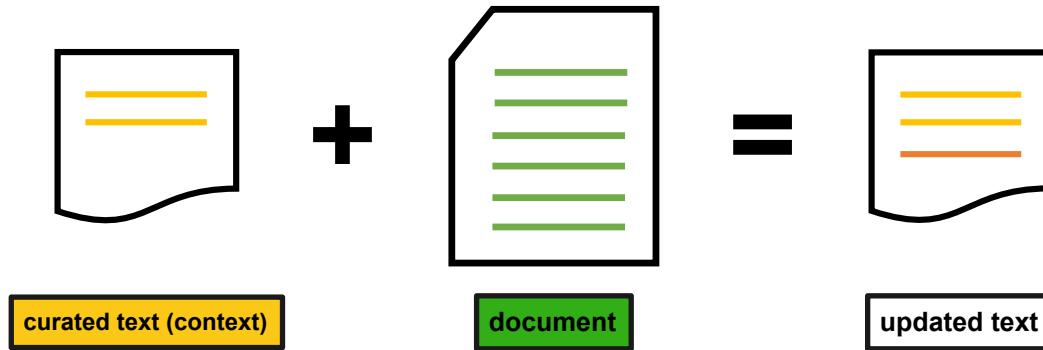
Primary Contribution



Primary Contribution



Primary Contribution



- design a task to perform content transfer from an unstructured source of information
- release dataset

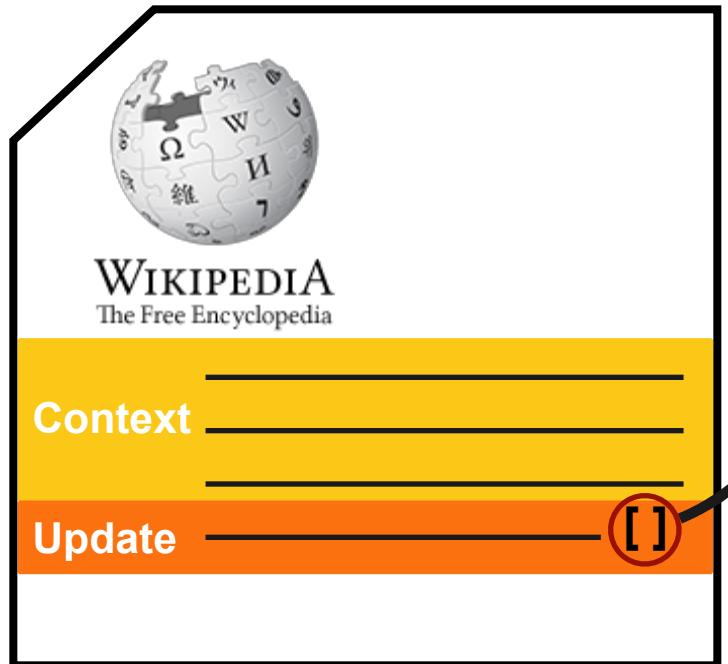
Data Creation Process



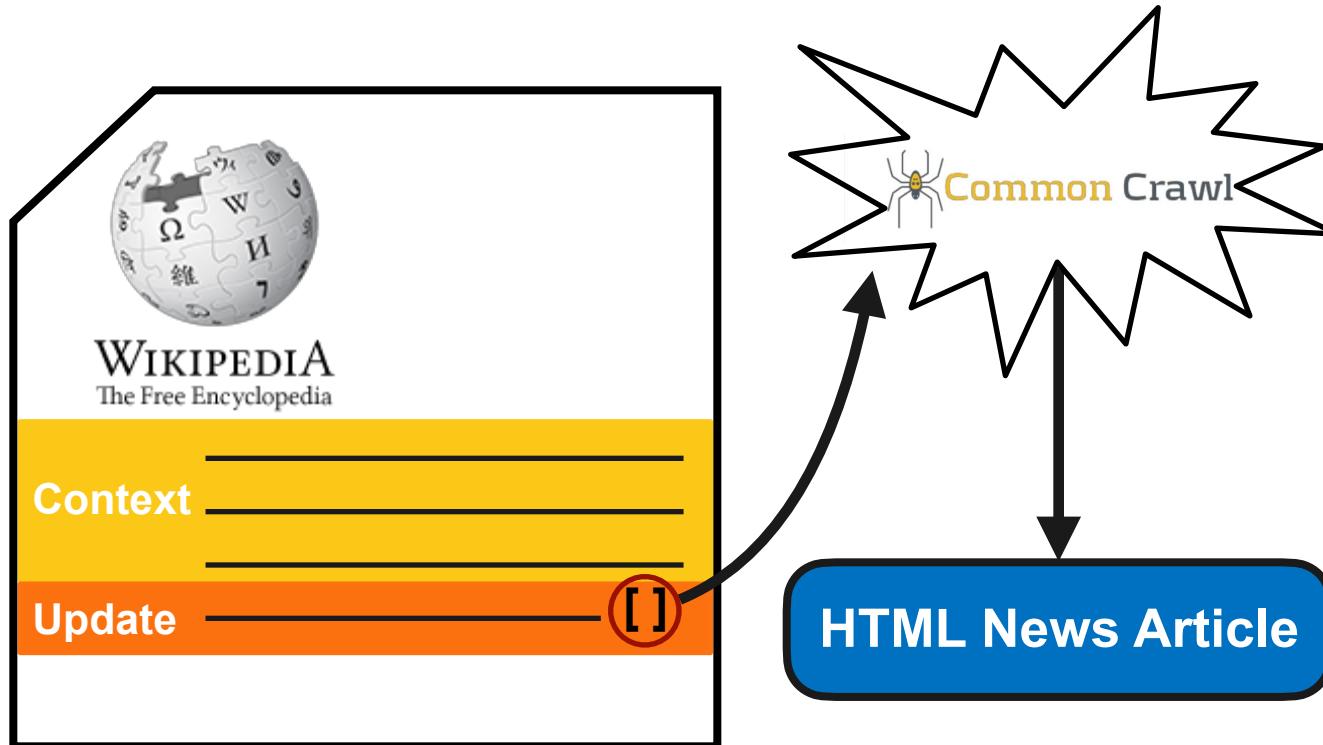
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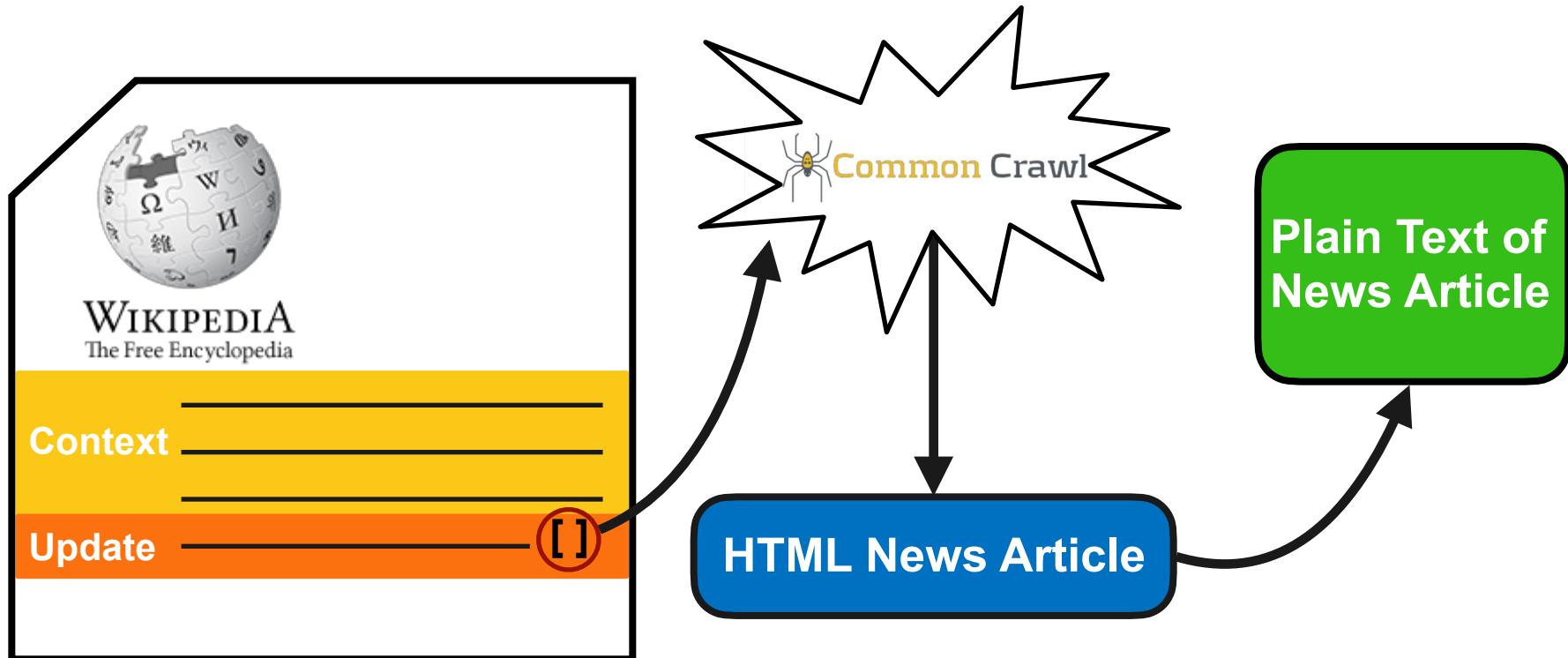
Data Creation Process



Data Creation Process



Data Creation Process



Data Creation Process

Total Data Size: 636K

News Article	Wikipedia Context	Update
...
...

Models

Generative Models

- Context Agnostic Generative Model (CAG) — Baseline
- Context Informed Generative Model (CIG)
- Context Responsive Generative Model (CRG)

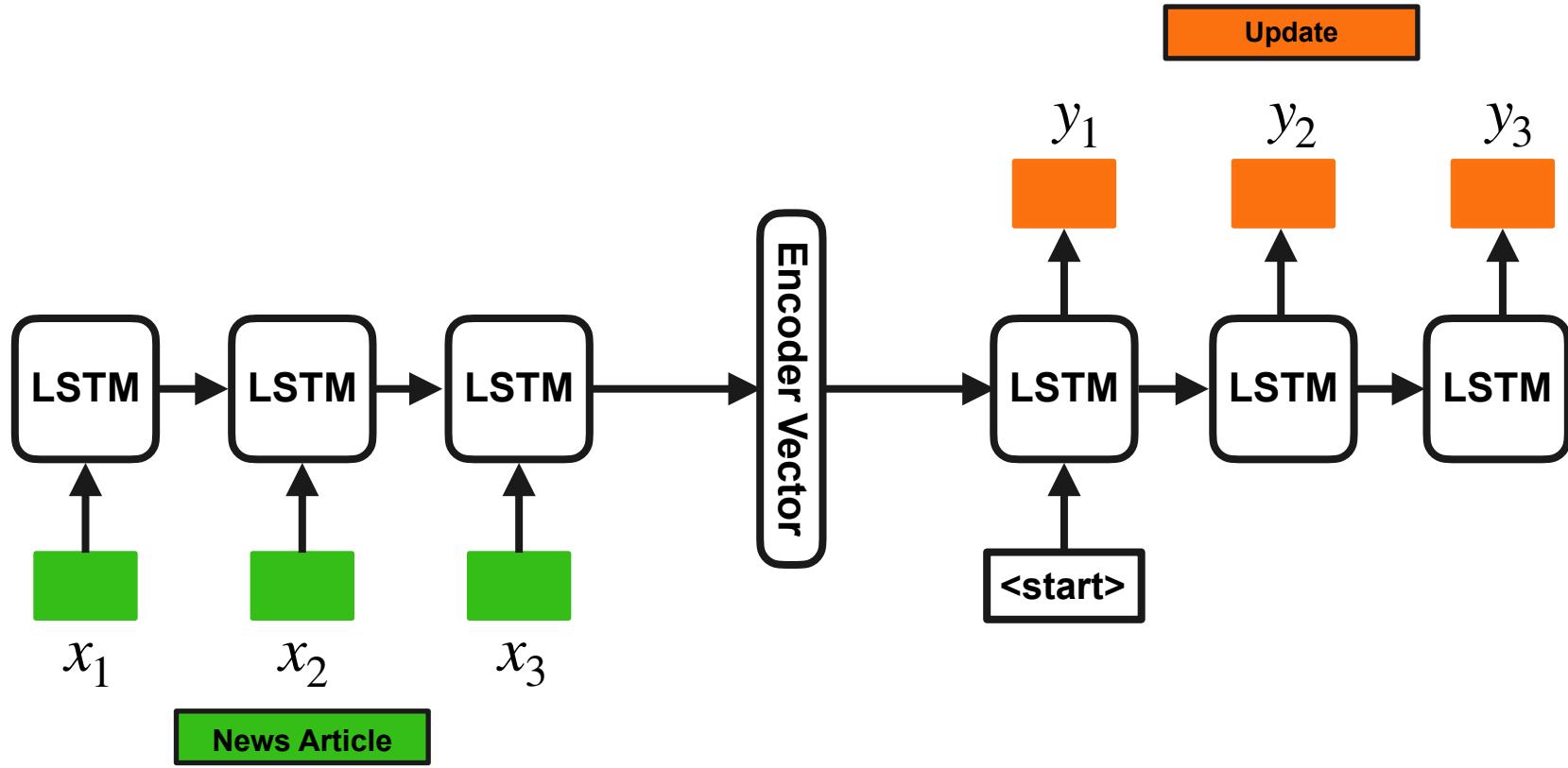
all models have global attention

Extractive Models

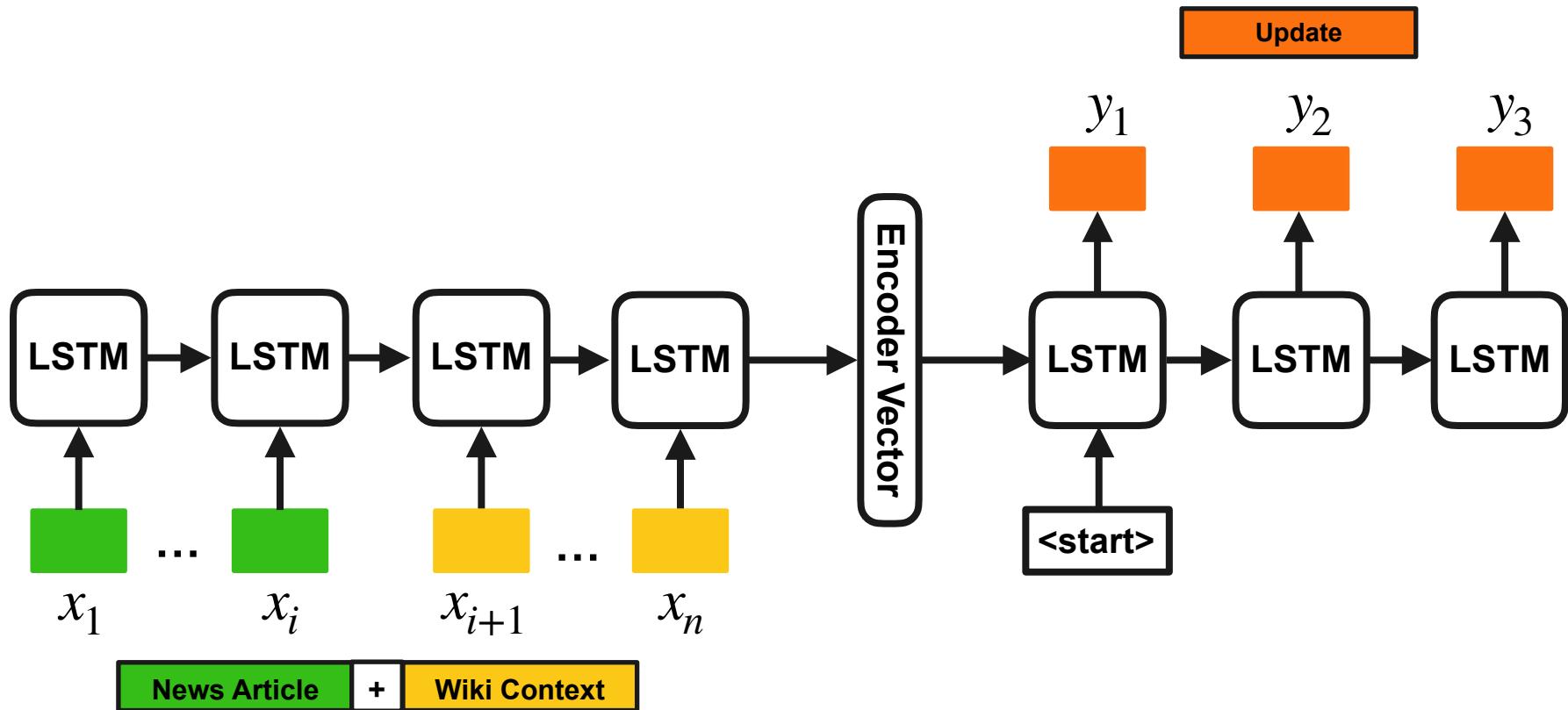
- SumBasic
- Context Informed SumBasic
- Oracle

all models are simplistic to infer if context helps in generation

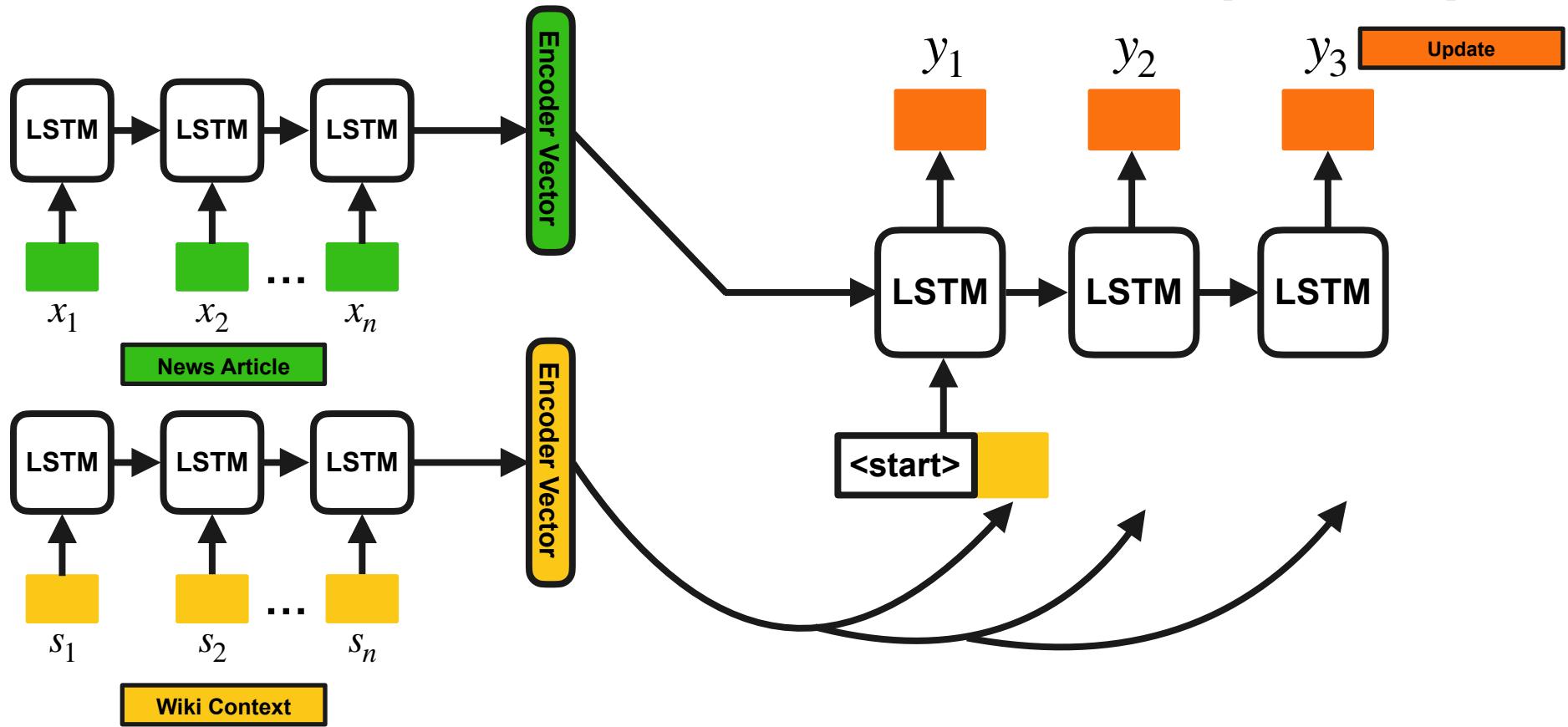
Context Agnostic Model (CAG) - Baseline



Context Informed Model (CIG)



Context Receptive Model (CRG)

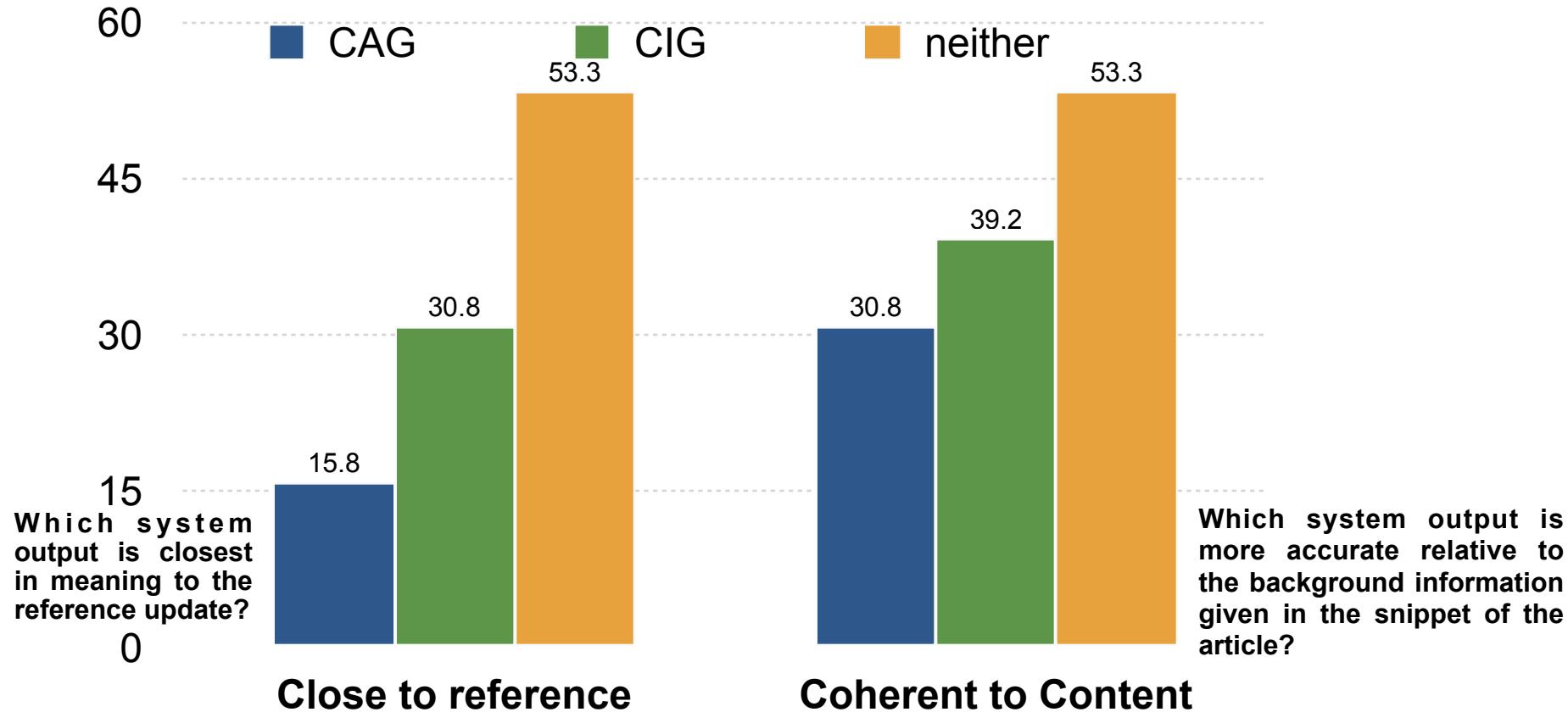


Automated Evaluation

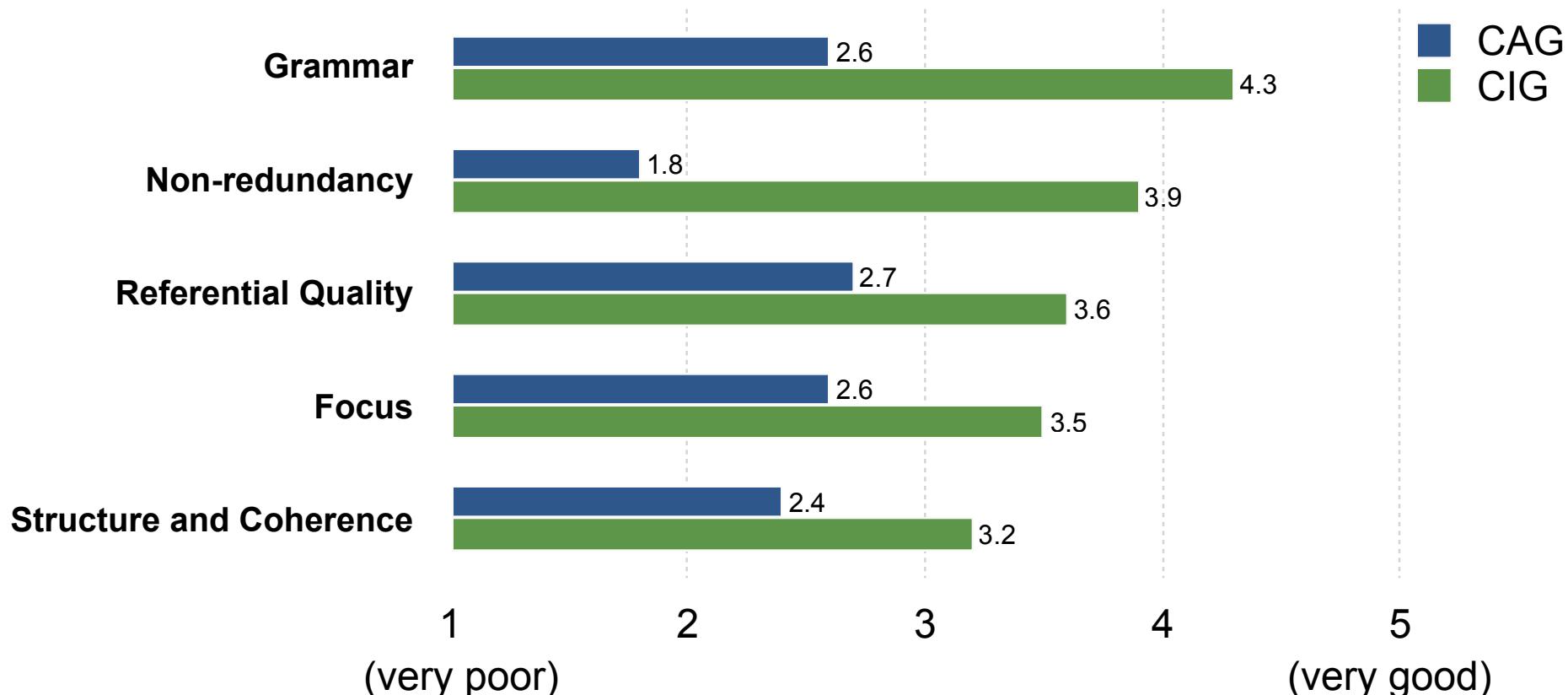
Model	ROUGE-L
SumBasic	5.6 (5.6-5.7)
Context Informed SumBasic	7.0 (7.0-7.1)
Context Agnostic Generative Model	9.1 (9.0-9.2)
Context Informed Generative Model	16.0 (15.9-16.1)
Context Receptive Generative Model	14.7 (14.6-14.8)
Oracle	28.8 (28.7-29.0)

* METEOR and BLEU numbers are consistent with ROUGE-L

Relative Human Evaluation



Absolute Quality Evaluation



Proposed Work

- ***Methodology***
 - Extending existing architectures for new tasks
 - Attention is under explored
- ***Evaluation***
 - No automatic metric to check *content fidelity*
 - Information generated exists in document

Methodology

- Attention based technique to incorporate unstructured data for grounded generation

$$p_t = \sigma(W_o o_t)$$

decide whether to focus on
Wiki context or News article
to generate current token

$$\tilde{p}_t = p_t W_1 a_t^c + (1 - p_t) W_2 a_t^s$$

$$\tilde{o}_t = \tanh(W_p [\tilde{p}_t; o_t])$$

Methodology

- Attention based technique to incorporate unstructured data for grounded generation

$$p_t = \sigma(W_o o_t)$$

calculate attention according
to this decision

$$\tilde{p}_t = p_t W_1 a_t^c + (1 - p_t) W_2 a_t^s$$

$$\tilde{o}_t = \tanh(W_p [\tilde{p}_t; o_t])$$

a_t^c = attention weights
of Wiki context
 a_t^s = attention weights
of News article

Methodology

- Attention based technique to incorporate unstructured data for grounded generation

$$p_t = \sigma(W_o o_t)$$

Change the output state
based on this decision

$$\tilde{p}_t = p_t W_1 a_t^c + (1 - p_t) W_2 a_t^s$$

$$\tilde{o}_t = \tanh(W_p[\tilde{p}_t; o_t])$$

Evaluation

- Information Extraction System (IE)
 - OpenIE, Comet, RAKE
- $i_r = IE(\text{reference})$, $i_g = IE(\text{generation})$,
 $i_s = IE(\text{context})$, $i_d = IE(\text{document})$
 - *Close to reference:* $\text{Sim}(i_r, i_g)$
 - *Coherent to context:* $\text{Sim}(i_g, i_s)$
 - *Information from source:* $\text{Sim}(i_g, i_d)$
 - $\text{Sim}()$ is Jaccard similarity, BLEU, BERT space similarity

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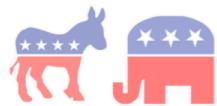
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Overview

Controlled Generation Schema



draft ✓
COLING '20



draft ACL '20 ✓
Storytelling '19
ACL '18

Content



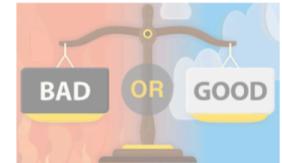
NAACL '19 ✓
EMNLP '18

Structure



draft ACL '20
draft ICML '20

Ethical Considerations



WiNLP '19

Sentence Ordering Task

Before

Ironman steals the Infinity Stones back from Thanos and uses them to disintegrate Thanos and his army, at the cost of his life.

Hulk travels to New York City in 2012 and convinces the Ancient One to give him the Time Stone.

Thor decapitates Thanos.

Five years later, AntMan escapes from the quantum realm.

Ironman builds a time machine to save the world.

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Problem Framing

- Prior Work
 - *Sequence Prediction Task*
 - *Hierarchical models* to learn document structure
- Our Approach
 - *Constraint Solving Problem*

Methodology

- For a document with n sentences ($\{s_1 \dots s_n\}$)
 - $|\mathcal{C}| = \binom{n}{2}$ constraints
 - Predicted constraints of the form $s_1 < s_2$
 - 4 sentences in a document then 6 constraints
 - $\{s_1 < s_2, s_1 < s_3, s_1 < s_4, s_2 < s_3, s_2 < s_4, s_3 < s_4\}$
 - Topological sort to find an order given \mathcal{C}
 - Graph: $s_1 \rightarrow s_2$ if $s_1 < s_2$

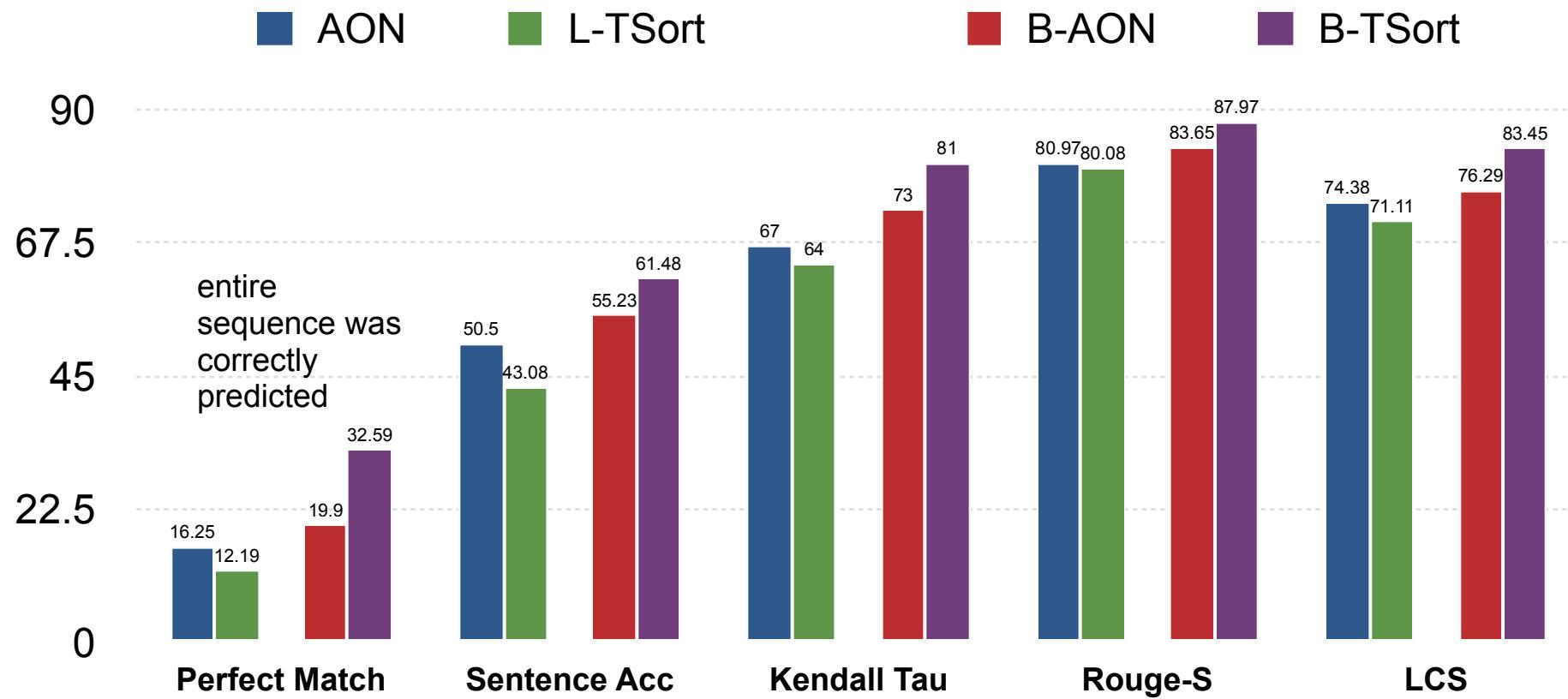
Constraint Learning

- *BERT based Representation (B-TSort)*
 - Next Sentence Prediction
 - $\text{MLP}(\text{BERT}(s_1[\text{SEP}]s_2))$
- *LSTM based Representation (L-TSort)*
 - $\mathbf{h}_1 = \text{LSTM}(s_1); \mathbf{h}_2 = \text{LSTM}(s_2)$
 - $\text{MLP}([\mathbf{h}_1; \mathbf{h}_2])$

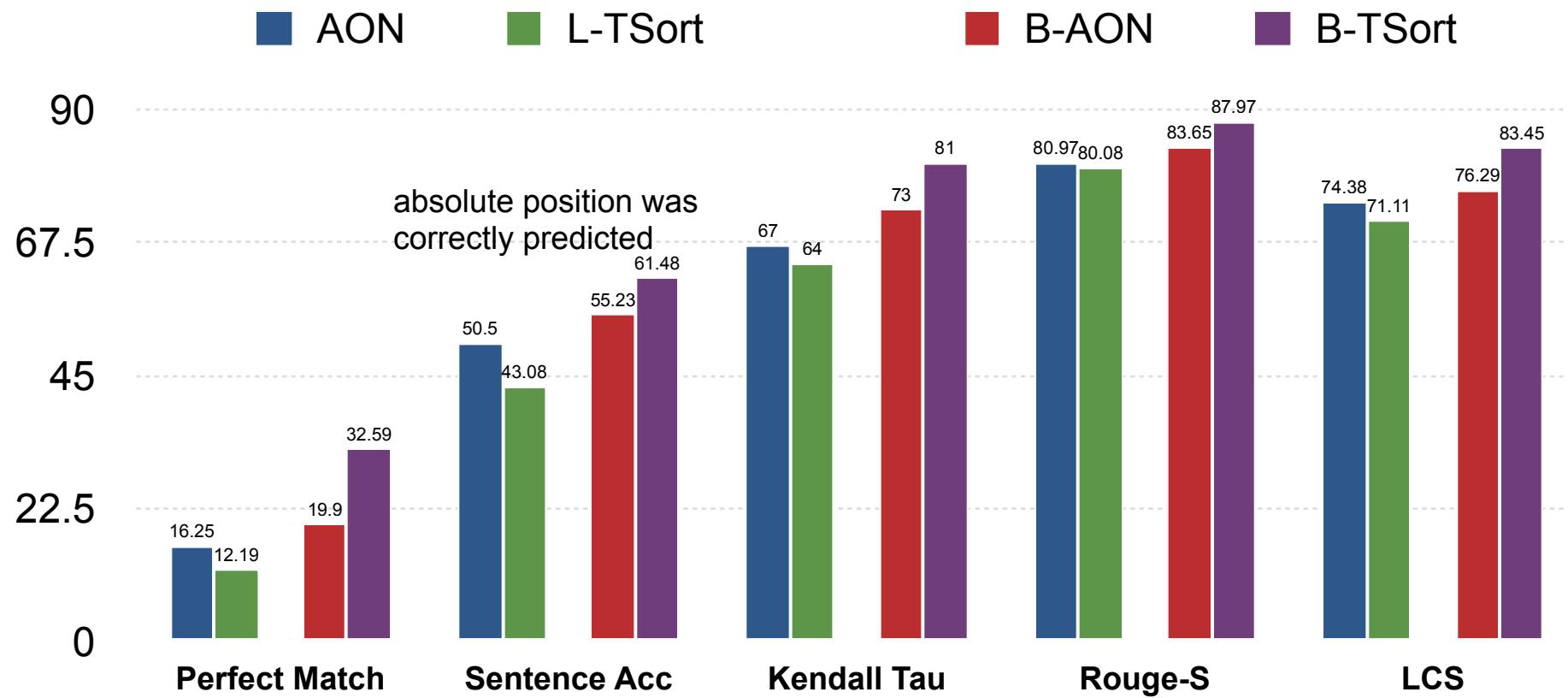
Baselines

- ***Attention Order Network (AON)***
 - LSTM: sentence representation
 - Transformer: document representation
 - LSTM decoder: generate order
- ***BERT Attention Order Network (B-AON)***
 - BERT: sentence representation

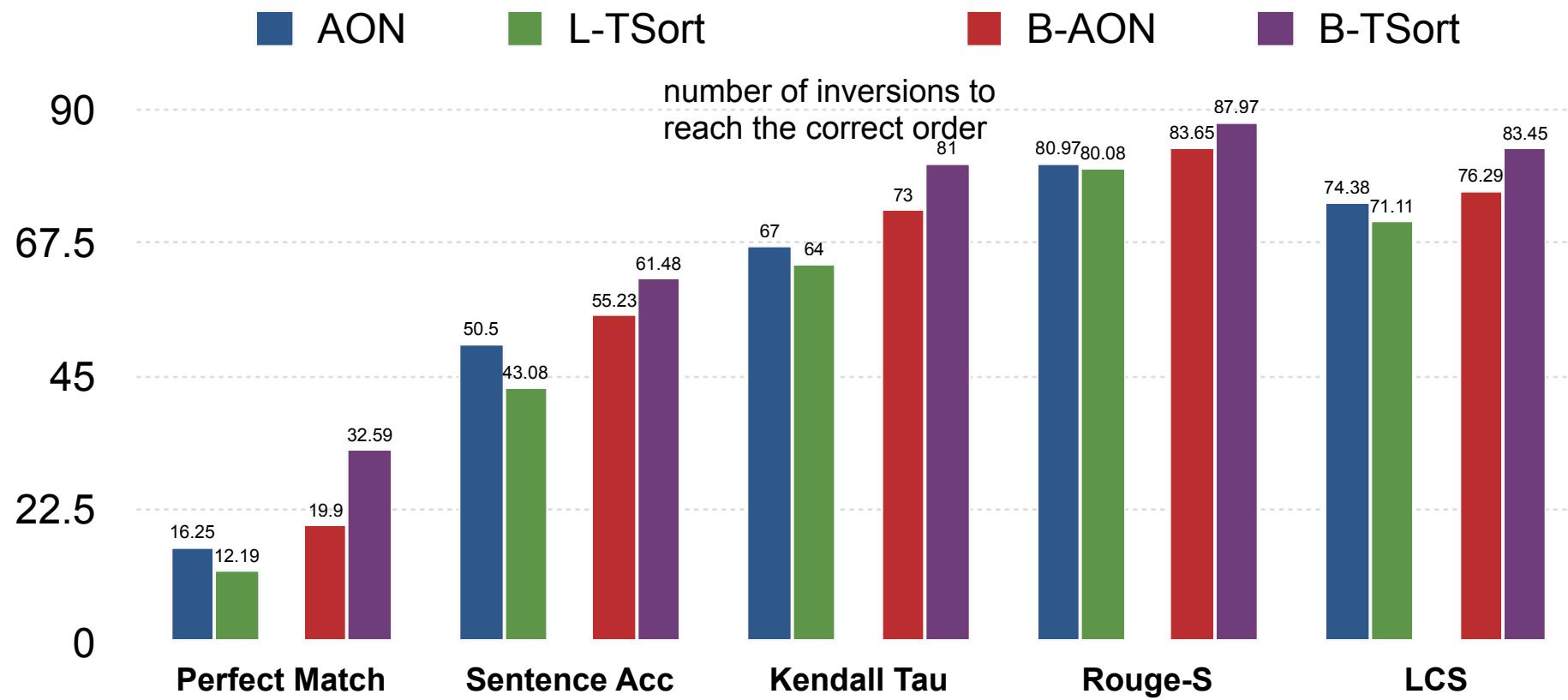
Results for NIPS abstracts



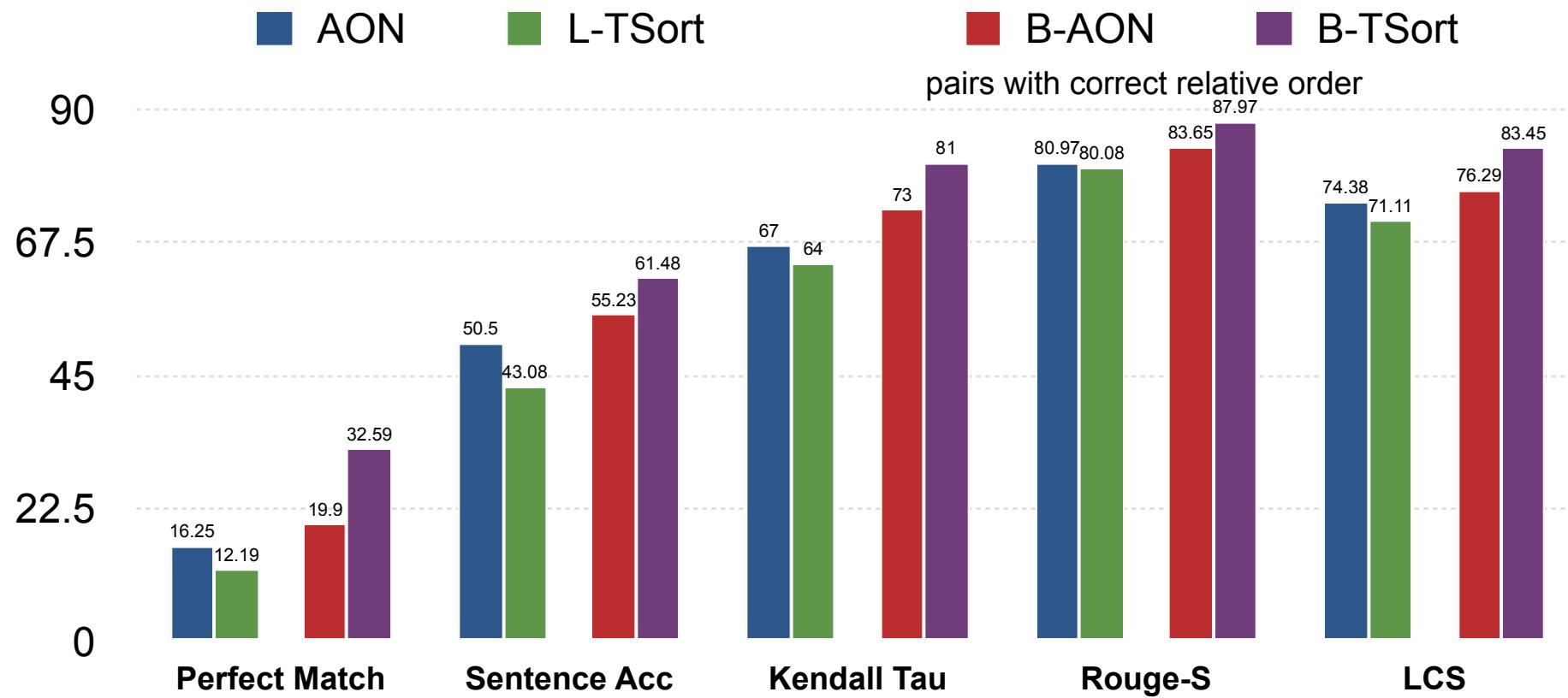
Results for NIPS abstracts



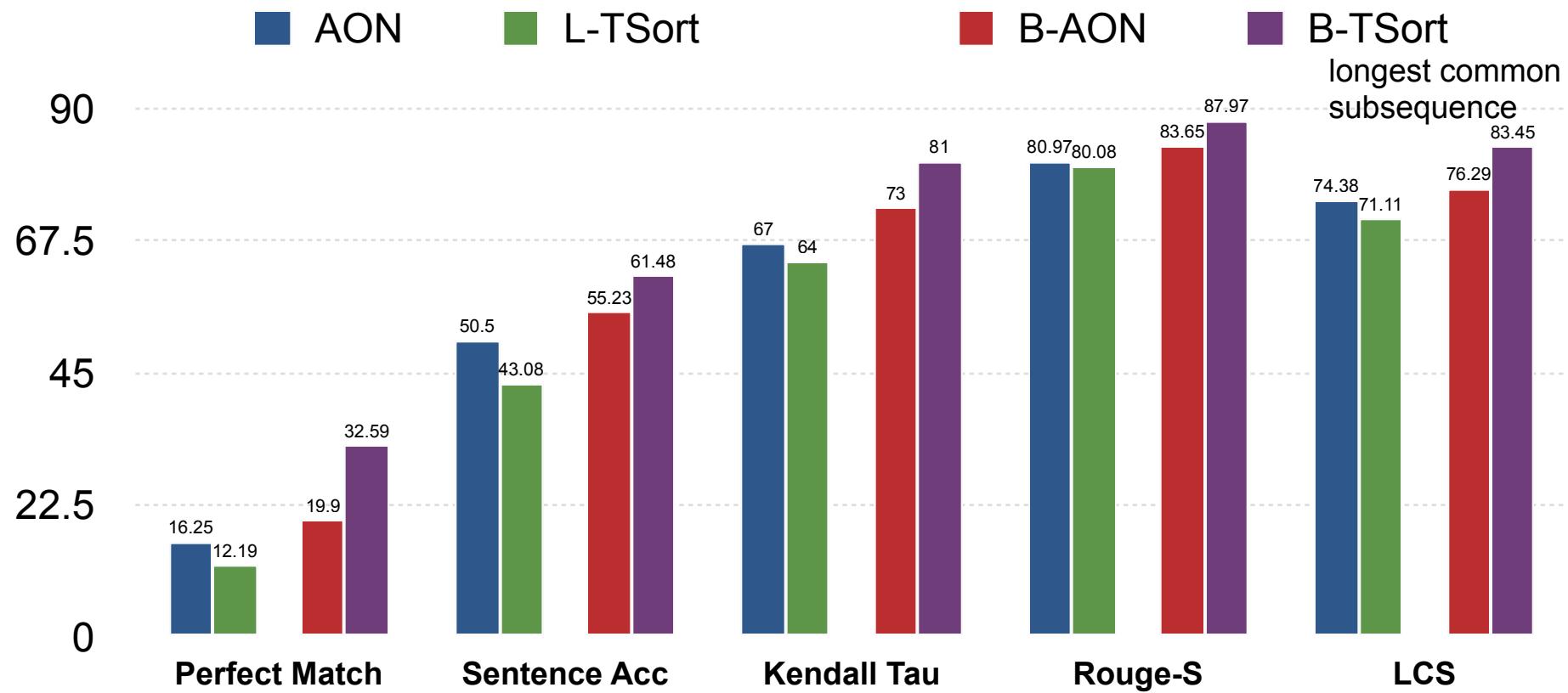
Results for NIPS abstracts



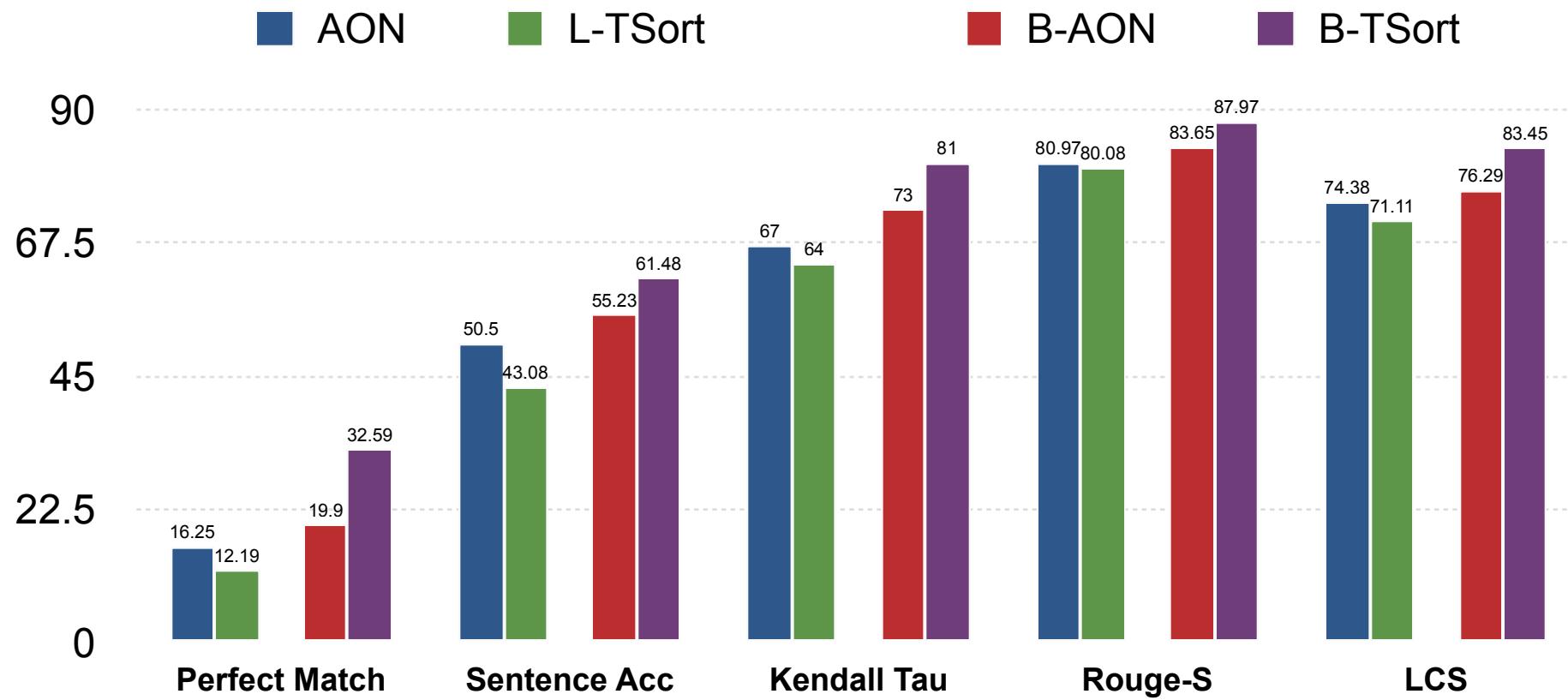
Results for NIPS abstracts



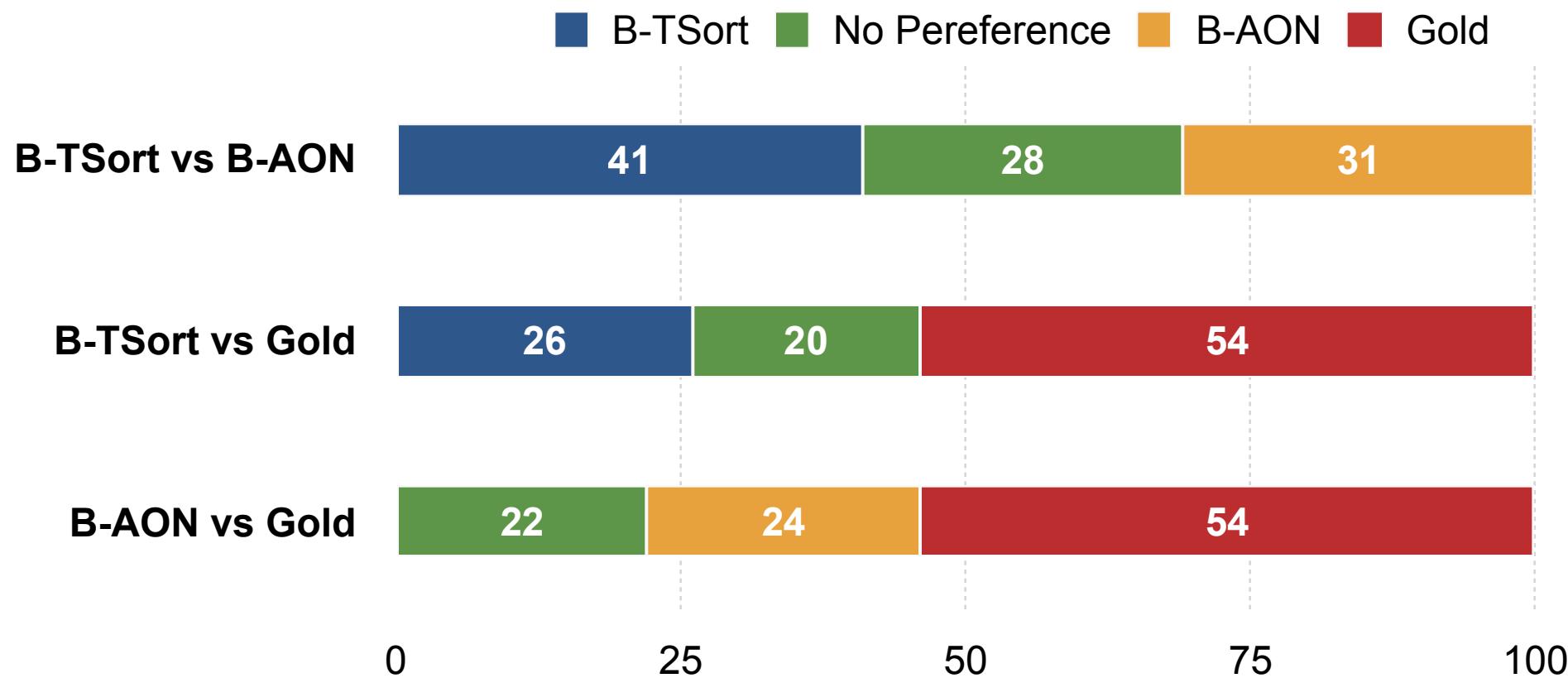
Results for NIPS abstracts



Results for NIPS abstracts



Results for Human Evaluation



Results

- B-TSort performs best in all metrics for SIND captions, NSF abstract, AAN abstract datasets
- Analysis of *displaced sentences*
- Analysis of documents with more than 10 sentences
- Percentage of *mismatch* in input and output for AON

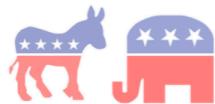
Overview

Controlled Generation Schema



*draft
COLING '20*

Style



*draft ACL '20
Storytelling '19
ACL '18*

Content



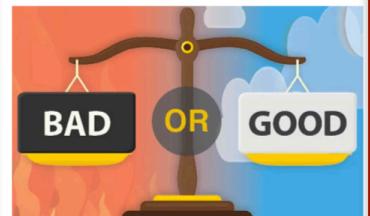
*NAACL '19
EMNLP '18*

Structure



*draft ACL '20
draft ICML '20*

Ethical Considerations



WiNLP '19

Ethical Considerations

- Swear words, obscenity, bias, hate speech
- Broader Impact of controllable text generation
- Social good and bad applications
 - Generate persuasive tweets to spread awareness about climate change
 - Generate persuasive social media content to keep people away from vaccines

Proposed Work

- ***Generating Balanced Datasets***
 - Preserve distributional properties of style transfer
 - Analyze the distribution on sentiment class for the gender transfer and vice versa
 - New way of evaluating style transfer
 - Does demographically balanced dataset lead to better sentiment analysis models?

Overview

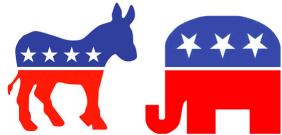
Controlled Generation Schema



*draft
COLING '20* ✓

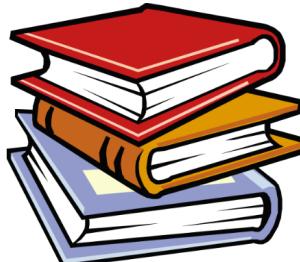
*draft
COLING '20* ✓

Style



*draft ACL '20
Storytelling '19
ACL '18* ✓

Content



*NAACL '19
EMNLP '18* ✓

Structure



*draft ACL '20
draft ICML '20* ✓

Ethical Considerations



WiNLP '19 ✓

Timeline

May - Aug
2020

Internship at Salesforce
Empirical evaluation of the controllable text generation techniques
Attention based technique for content grounded generation

Sep - Dec
2020

Techniques to build effective style representation
Ablation analysis of classifier to computationally understand style

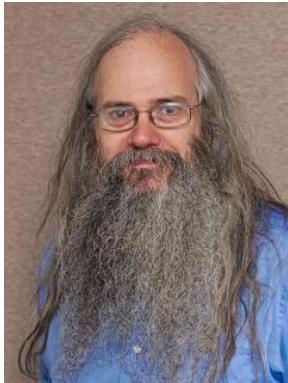
Jan - Feb
2021

Ethical considerations, analysis of style transfer models,
generate demographically balanced dataset

Mar - Apr
2021

Apply for job and write thesis

Thank You!



Alan W Black (co-advisor)



Ruslan Salakhutdinov (co-advisor)



Yulia Tsvetkov



Jason Weston