

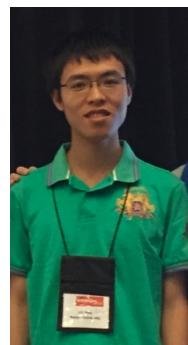


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CGMH: Constrained Sentence Generation by Metropolis-Hastings Sampling

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Outline

- Motivation and Constrained Sentence Generation
- Limitation of Existing Methods
- Overview of CGMH
- Experiments
 - Keyword to sentence
 - Paraphrasing
 - Sentence Error Correction
- Conclusion

Motivation: Design Advertisement Slogans



Keywords from Advertiser

Rin clothes bright



Advertisement Slogan

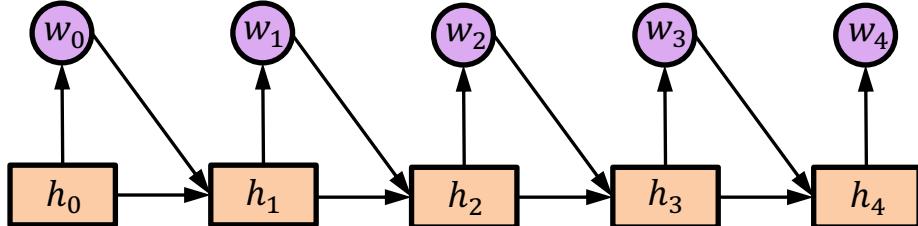


Problem Definition

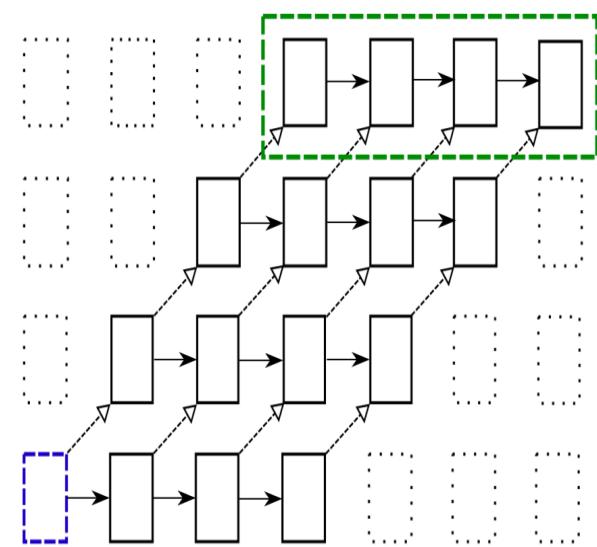
- Generating sentence satisfying constraints:
- Hard constraints: Keyword must occur in sentences (e.g. keyword2sentence task)
 - E.g. Juice -> Brand natural juice, specially made for you
- Soft constraints: Semantically similar to a given sentence (e.g. paraphrase task)
 - E.g. The movie is great -> It is one of my favorite movies

Existing Approach: Grid Beam Search or RNN with Separate decoding

- LSTM with Grid beam search

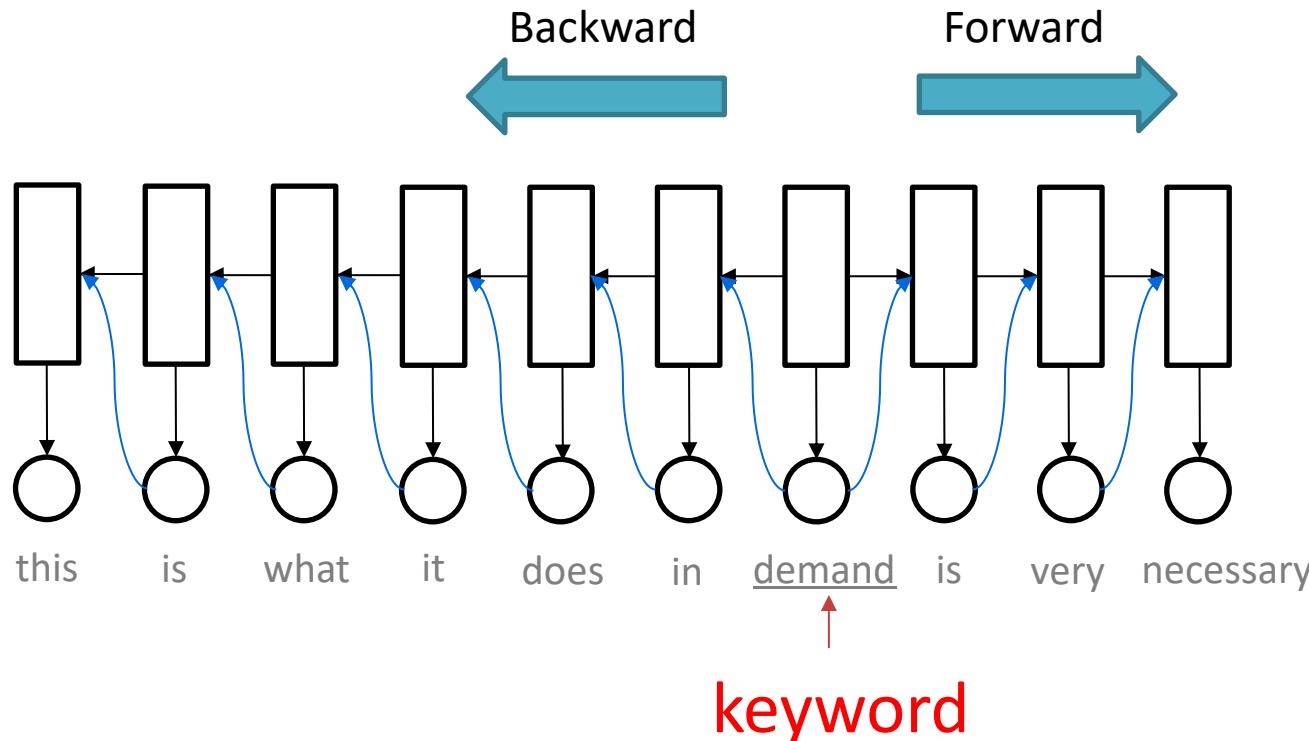


Constraint
3
Constraint
2
Constraint
1
No
constraint
s



LSTM with Separate Backward forward decoding: limited to one keyword

- LSTM w/ sep-B/F, which generates **independent backward and forward sequences** from the given word.



LSTM with Separate Backward forward decoding: limited to one keyword

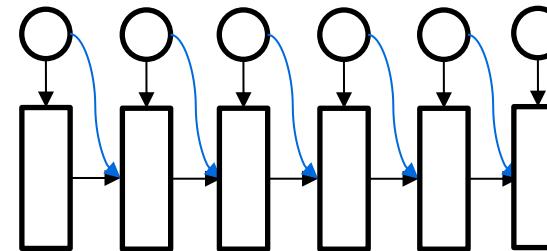
keyword

- LSTM w/ asyn-B/F, which **first generates the first half of a sentence and then generates another half conditioned on the first half.**

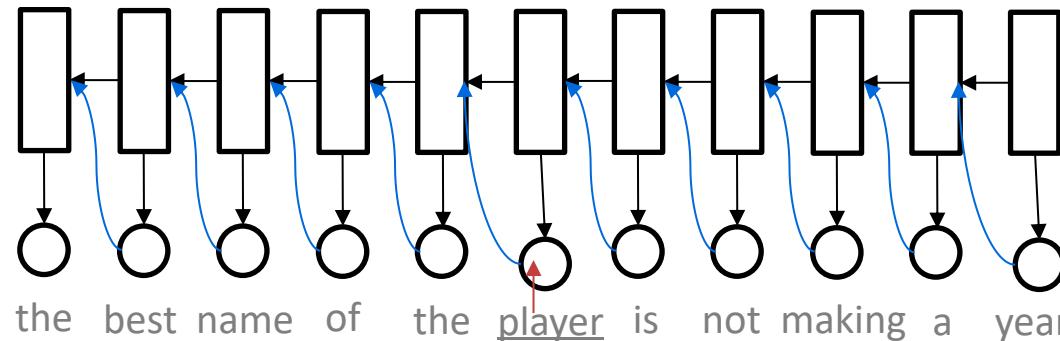
Step1: Forward



player is not making a year



Step2: Backward



keyword

Formulation in Proposed CGMH

- To generate samples (sentences) from the target distribution

$$\pi(x) = \prod_t P(x_t|x_{0:t-1}) \cdot \prod_i P_C^i(x)$$

language model probability



Indicator(0-1) function for constraints

Challenge

- To generate samples (sentences) from the target distribution

$$\pi(x) = \prod_t P(x_t|x_{0:t-1}) \cdot \prod_i P_C^i(x)$$

↑
language model probability ↑
Indicator(0-1) function for constraints

- $\pi(x)$ is high-dimensional, and no direct sampling method.

Main Idea of CGMH

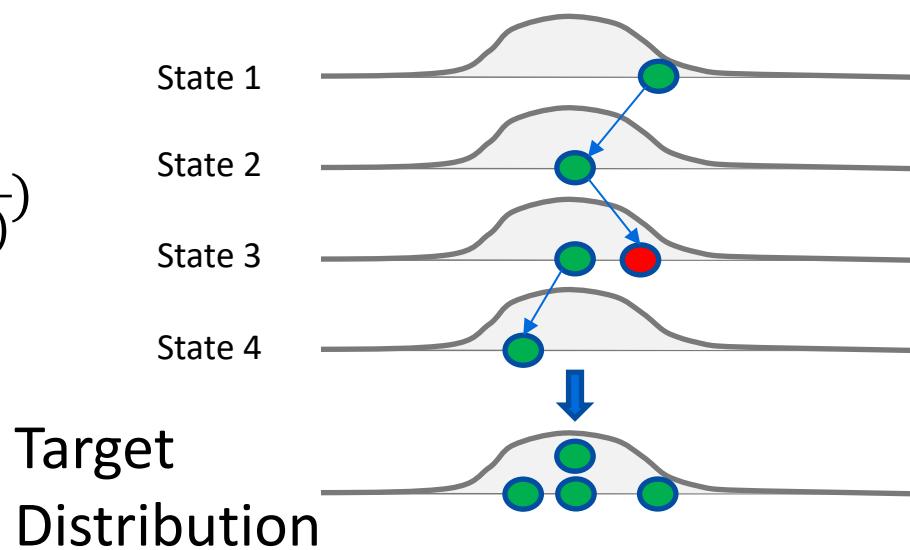
- Instead of sampling from $\pi(x)$ directly, generate samples iteratively:
 - Starting with initial keywords
 - next sentence based on modification of previous
 - action proposals to modify the sentences
- Metropolis-Hastings Algorithm

Background: Metropolis–Hastings sampling

- Metropolis-Hastings(MH) perform sampling by first **proposes** a transition, and then **accepts or rejects** the transition.

$$A(x'|x_{t-1}) = \min\left(1, \frac{\pi(x') \cdot g(x_{t-1}|x')}{\pi(x_{t-1}) \cdot g(x'|x_{t-1})}\right)$$

g is proposal distribution



CGMH

➤ CGMH performs constrained generation by:

1. Pretrain Language Model prob;
2. Start from a initial sentence x_0 ;
3. Propose a new sentence x_t from x_{t-1} , and accept/reject the action. Action proposal include:
 - I. Replacement: change a word to another one
 - II. Insertion: add a word
 - III. Deletion: remove a word

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space.**

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space.**

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space.**

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life
7	Replace	Accept	BMW , the sports car of future life

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space.**

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life
7	Replace	Accept	BMW , the sports car of future life
8	Insert	Accept	BMW , the sports car of the future life

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life
7	Replace	Accept	BMW , the sports car of future life
8	Insert	Accept	BMW , the sports car of the future life
9	Delete	Reject	BMW , the sports car of the future life

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life
7	Replace	Accept	BMW , the sports car of future life
8	Insert	Accept	BMW , the sports car of the future life
9	Delete	Reject	BMW , the sports car of the future life
10	Delete	Accept	BMW , the sports car of the future life

Illustration of CGMH

- CGMH performs Metropolis-Hastings **sampling directly in sentence space**.

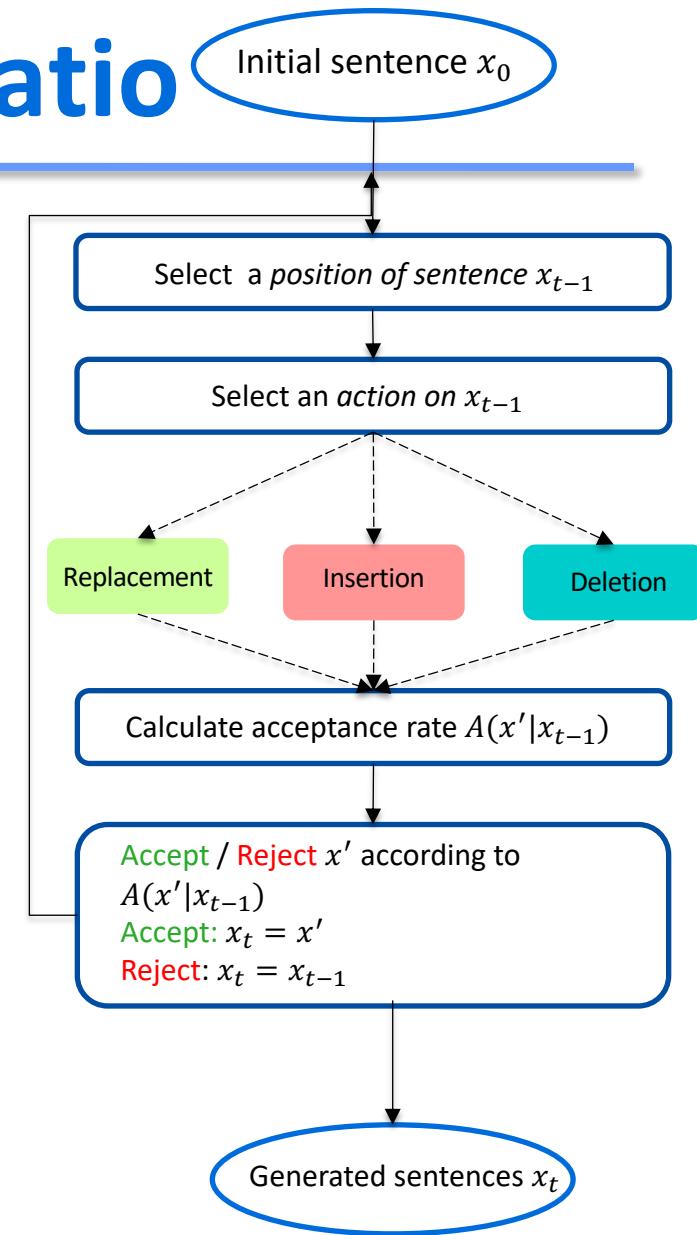
Step	Action	Acc/Rej	Sentences
0	[Input]		BMW sports
1	Insert	Accept	BMW sports car
2	Insert	Accept	BMW the sports car
...
6	Insert	Accept	BMW , the sports car of daily life
7	Replace	Accept	BMW , the sports car of future life
8	Insert	Accept	BMW , the sports car of the future life
9	Delete	Reject	BMW , the sports car of the future life
10	Delete	Accept	BMW , the sports car of the future life
11	[Output]		BMW , the sports car of the future

CGMH: Acceptance Ratio

- Calculate the acceptance rate:

$$A(x'|x_{t-1}) = \min\left(1, \frac{\pi(x') \cdot g(x_{t-1}|x')}{\pi(x_{t-1}) \cdot g(x'|x_{t-1})}\right)$$

- Accept x' with probability $A(x'|x_{t-1})$

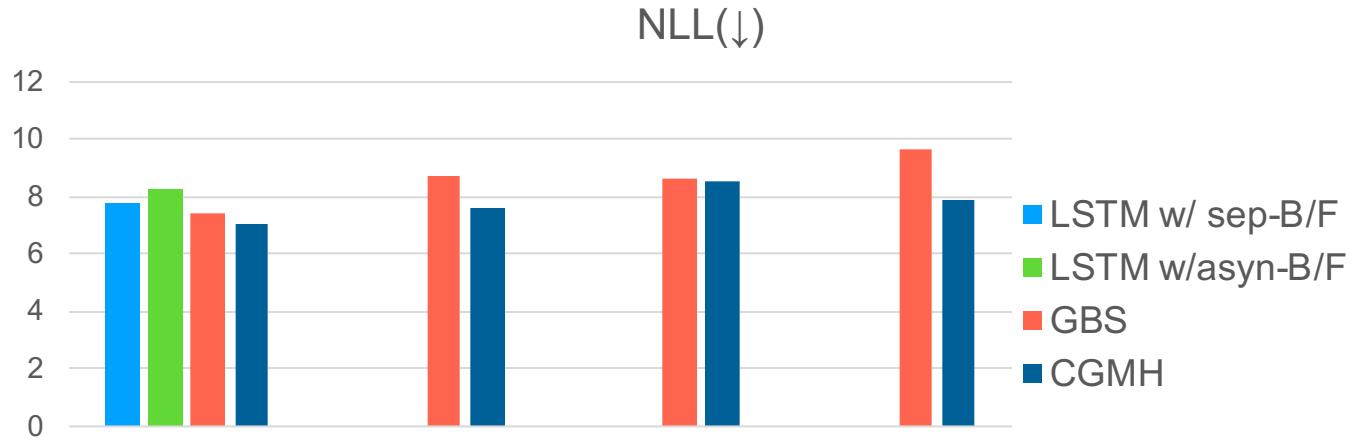


Experiment

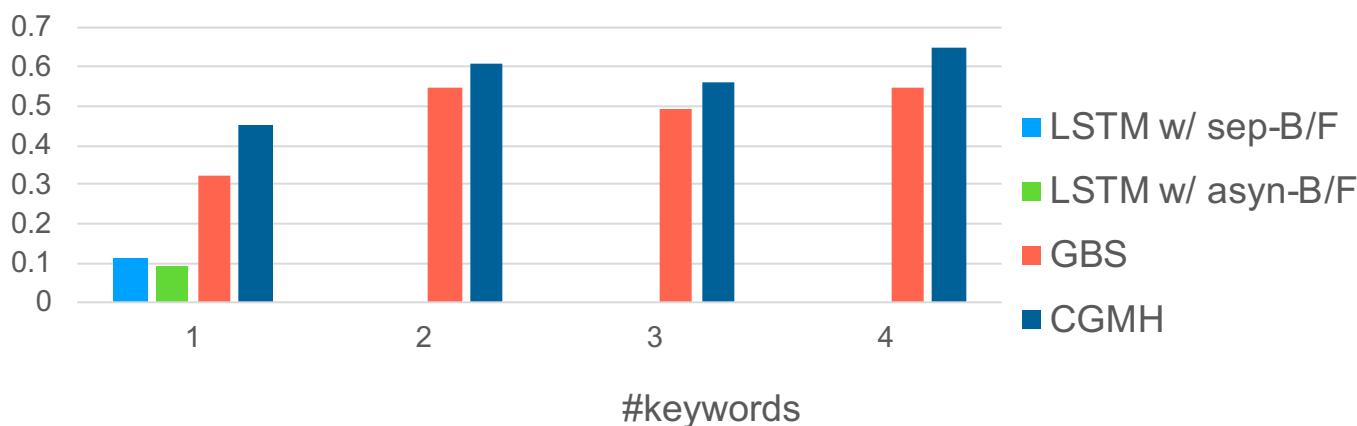
- Keywords to Sentence Generation (*hard*)
- Unsupervised Paraphrase Generation
(*soft*)
- Sentence Correction (*soft*)

Experiment – Keywords to Sentence Generation

- CGMH outperforms previous work in both NLL and human evaluations.



Scores of human evaluation (\uparrow)



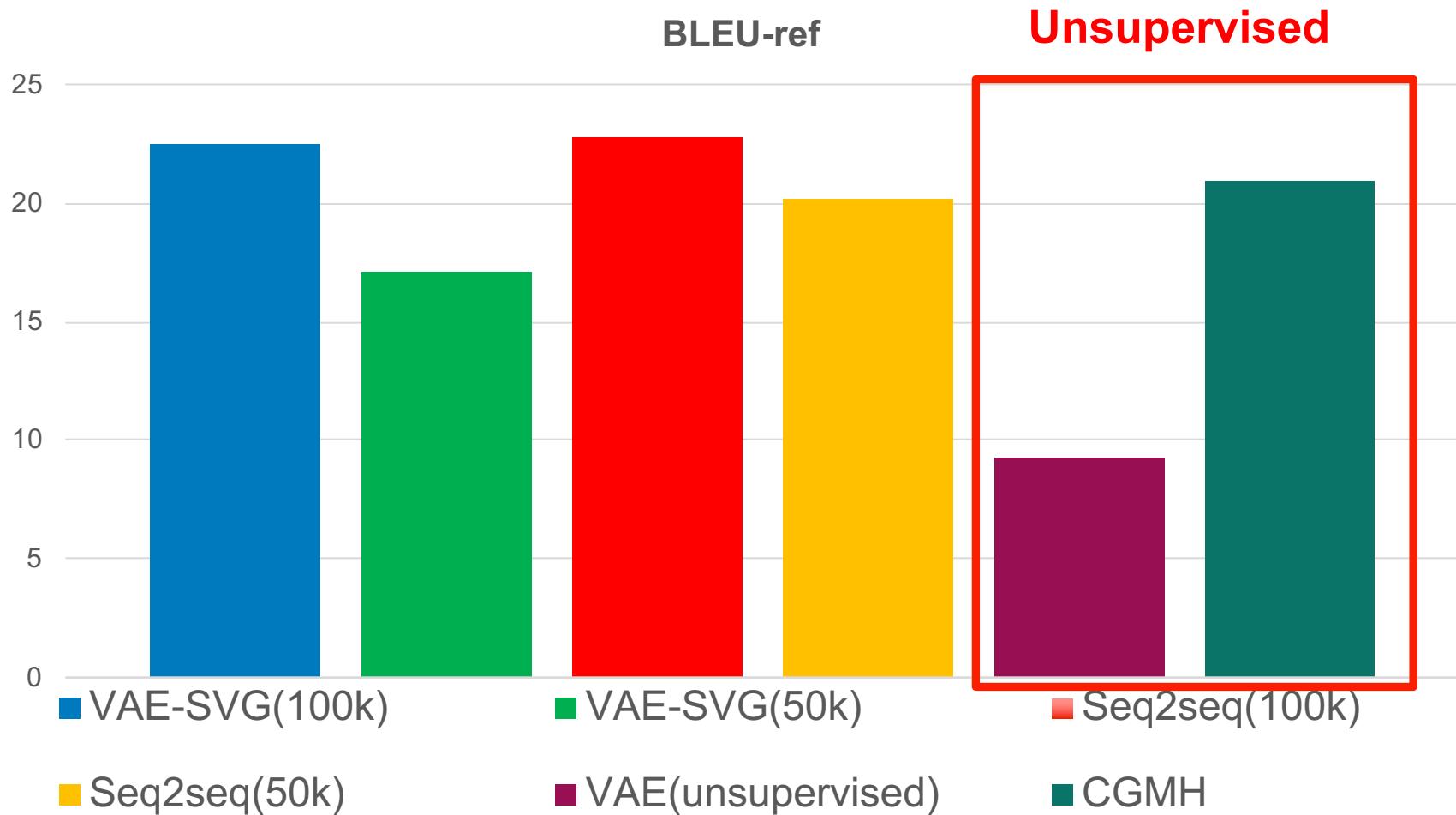
Keyword-to-Sentence: Showcase

- Examples of CGMH and GBS.

Keyword(s)	Generated Sentences	GBS
friends	My good friends were in danger .	But friends and family have been arrested .
project	The first project of the scheme .	The project , which is expected to be completed next year
have, trip	But many people have never made the trip .	But the trip has be completed .
lottery, scholarships	But the lottery has provided scholarships.	The lottery is a scholarship .
decision, build, home	The decision is to build a new home.	The decision builds a house for home .
attempt, copy, painting, denounced	The first attempt to copy the painting was denounced.	But attempt to copy painting will be denounced.

Experiment – Paraphrase Generation

- CGMH is the first unsupervised model to achieve comparable results with supervised models.



Experiment – Unsupervised Paraphrase Generation

- CGMH is the first unsupervised model to achieve comparable results with supervised models.

Examples

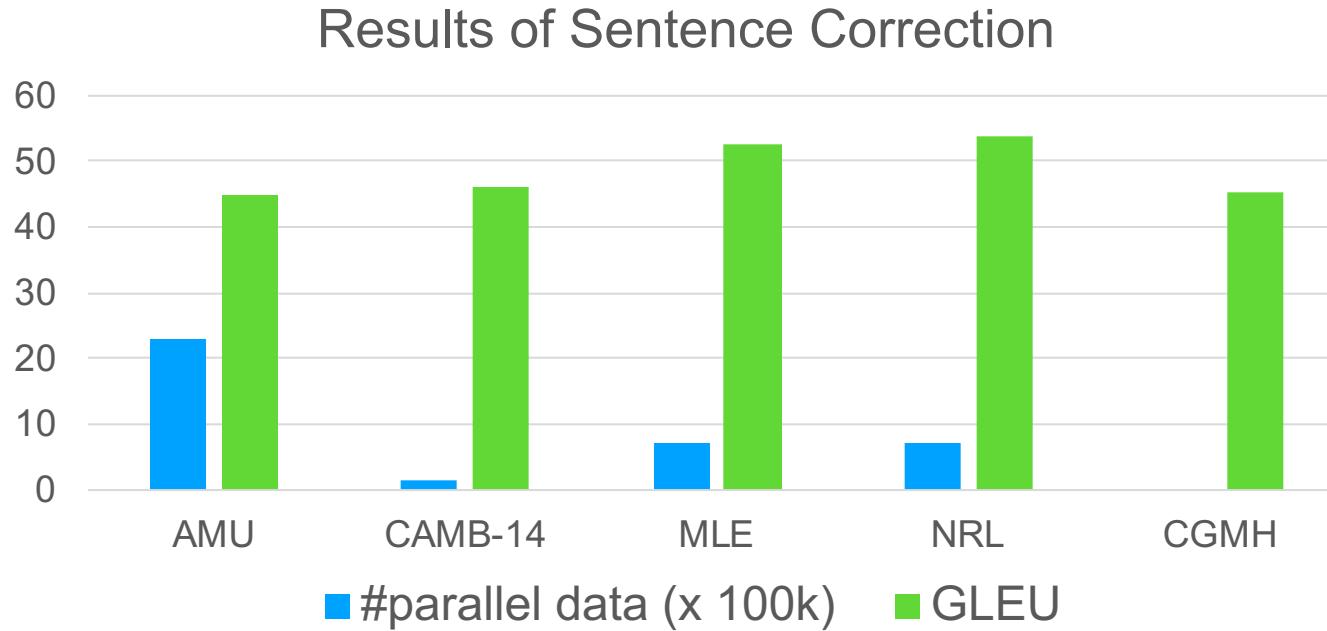
1, what 's the best plan to lose weight ->
what 's the best way to slim down quickly

2. how should i control my emotion ->
how do i control my anger

3. why do my dogs love to eat tuna fish ->
why do my dogs like to eat raw tuna and raw fish

Experiment – Unsupervised Error Correction

- CGMH outperforms some of the supervised models trained on large parallel corpus.
- Dataset: JFLEG, 1501 sentences



Experiment – Unsupervised Error Correction

- CGMH outperforms some of the supervised models trained on large parallel corpus.

Erroneous sen1	Even if we are failed , we have to try to get a new things .
Reference sen1	Even if we all failed , we have to try to get new things .
Output sen1	Even if we are failing , we have to try to get some new things ..
Erroneous sen2	In the world oil price very high right now .
Reference sen2	In today 's world , oil prices are very high right now .
Output sen2	In the world , oil prices are very high right now .

Conclusion

- CGMH is a Monte Carlo sentence generation algorithm capable of dealing with various constrained sentence generation.
- Method beyond DL such as Bayesian method still works
- Unsupervised method can achieve comparable performance to supervised methods in paraphrasing

Thanks!

- Contact: lileilab@bytedance.com
- Code is available at:
[`https://github.com/NingMiao/CGMH`](https://github.com/NingMiao/CGMH)

Reference

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Appendix – Properties of CGMH

➤ Property of CGMH:

1. *Detailed balance condition* is satisfied;
2. Sampling process is *irreducible* and *nonperiodic*.
3. So *ergodicity* of sampling from π is satisfied.

Appendix – $P_C(x)$ for different tasks

➤ For different tasks, we use different $P_C(x)$:

- Keywords2Sentence: $P_C(x) = 1_{\{x \text{ contains the keywords}\}}$
- Paraphrase: $P_C(x) = 1 / P_C^{KW}(x) / P_C^{KW}(x) P_C^{SIM}(x)$
- Correction: $P_C(x) = 1 / P_C^{WMA}(x)$

Appendix – Details of experiments

➤ Keywords to Sentence Generation (*hard*)

- Aim: To generate fluent sentences containing the given set of words.
- Dataset: A subset of One–Billion–Word Corpus (5M)
- Initial sentence: Keywords.

➤ Unsupervised Paraphrase Generation (*soft*)

- Aim: To generate sentences with similar meaning of the given one.
- Dataset: Quora(140k pairs of paraphrase sentences)
- Initial sentence: Original sentence.

➤ Sentence Correction (*soft*)

- Aim: To correct the errors in the given sentence.
- Dataset: A subset of One–Billion–Word Corpus (5M, base language model) and JFLEG(1501 sentences, for test only)
- Initial sentence: Erroneous sentence.