Supplementary Material for Multi-modal Dependency Tree for Video Captioning

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A Broader Impact

This paper introduces a novel video captioning method that generates sentences by constructing dependency trees. The proposed method offers a possible new way of generating fluent and relevant sentences for videos and may inspire more works that explicitly model the syntactic structure of sentences in natural language generation. It can also help develop more practical video processing systems, such as automatic video subtitling tools. However, such technique is still affected by the biases in the training data. When the videos involve minorities or uncommonly-seen subjects, it may produce undesired output or lead to inaccurate understanding of the video content. Thus, more future research is necessary to address this issue.

B Qualitative Analysis of Generated Tree Structure

We show some examples of the generated sentences on the MSVD dataset and the Charades Captions dataset in Figure 1 and Figure 2, respectively. As is shown in these figures, our method describes the human actions accurately and the sentences possess correct grammatical structure. These qualitative results show that our tree topology improves the fluency and relevancy of sentences by effectively capturing the syntactic structure and semantic relationship.

C Automatic Evaluation of Generated Tree Structure

To evaluate the quality of the generated tree structure, we calculate the average edit distance between the generated tree and the ground truth dependency trees using the algorithm proposed in [1]. A lower edit distance indicates that the generated tree is more similar to the ground-truth dependency trees. The evaluation results on the Charades Captions dataset are shown in Table 2.

D Details about Simple and Complex Subsets

For the Charades Captions and MSR-VTT datasets, the videos in the complex subset and simple subset are selected from the test split according to the average ground-truth sentence length. A video is in the simple subset if the average length of its ground-truth sentences is less of equal than p, and is in the complex subset otherwise. The distributions of the average ground-truth sentence length on the test splits of Charades Captions and MSR-VTT are shown in Figure 3a and Figure 3b, respectively. According to the sentence length distributions, the value of p on the Charades Captions dataset is set

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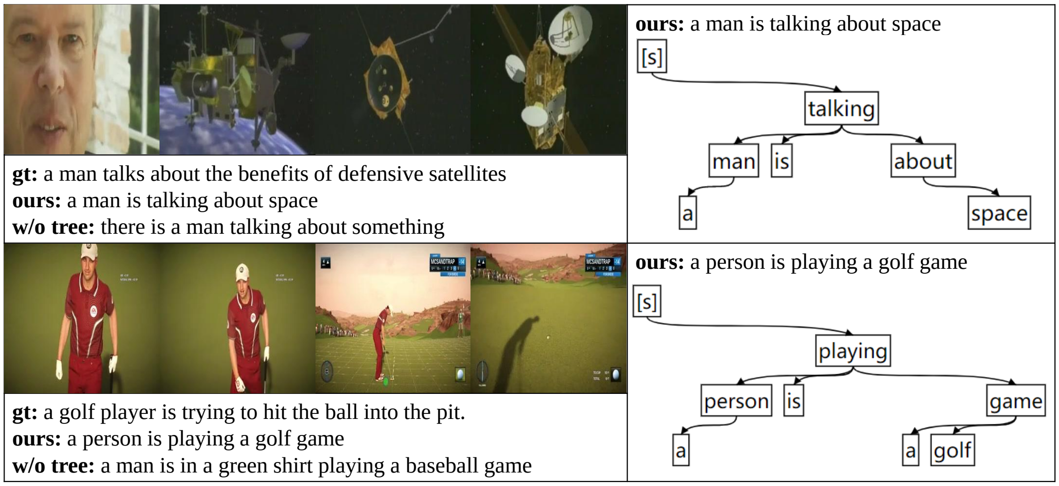


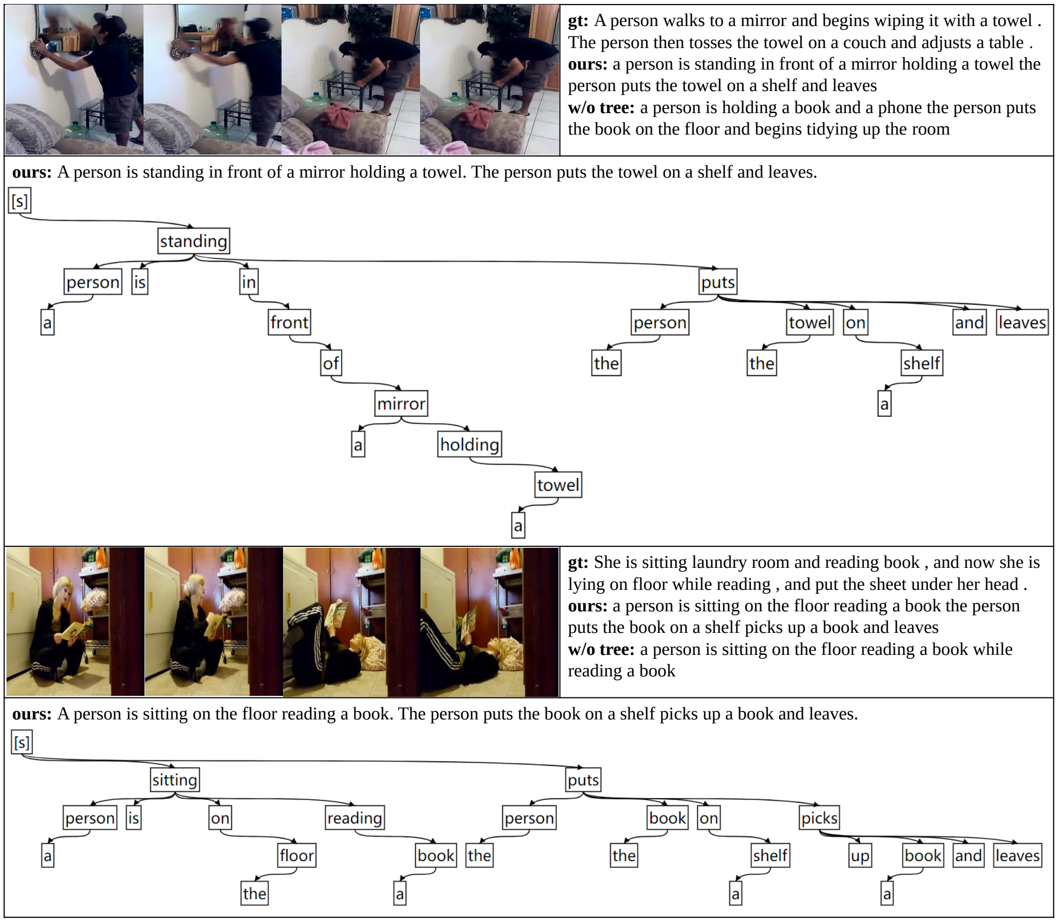
gt: a man talks about the benefits of defensive satellites
ours: a man is talking about space
w/o tree: there is a man talking about something

ours: a man is talking about space

gt: a golf player is trying to hit the ball into the pit.
ours: a person is playing a golf game
w/o tree: a man is in a green shirt playing a baseball game

ours: a person is playing a golf game

Figure 1: Qualitative results of the generated tree structure and sentences on the MSR-VTT dataset. “gt" and “ours” denote the ground-truth sentences and the output of our method, respectively. The sentences labeled with “w/o tree” are generated by the variant of our model that constructs chain-structured trees rather than dependency trees. The node with symbol $[s]$ on the top-left of the tree indicates the beginning of the sentence.



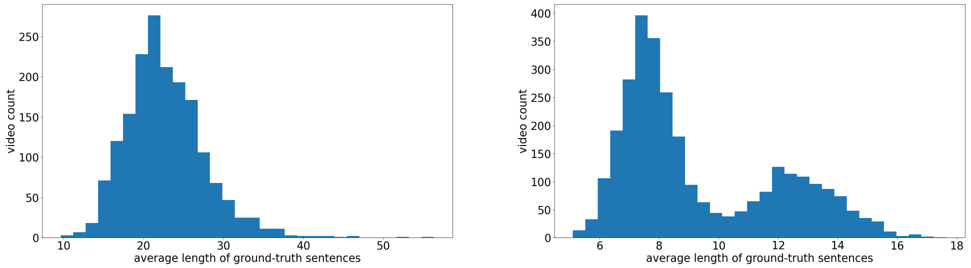
gt: A person walks to a mirror and begins wiping it with a towel . The person then tosses the towel on a couch and adjusts a table .
ours: a person is standing in front of a mirror holding a towel the person puts the towel on a shelf and leaves
w/o tree: a person is holding a book and a phone the person puts the book on the floor and begins tidying up the room

ours: A person is standing in front of a mirror holding a towel. The person puts the towel on a shelf and leaves.

gt: She is sitting laundry room and reading book , and now she is lying on floor while reading , and put the sheet under her head .
ours: a person is sitting on the floor reading a book the person puts the book on a shelf picks up a book and leaves
w/o tree: a person is sitting on the floor reading a book while reading a book

ours: A person is sitting on the floor reading a book. The person puts the book on a shelf picks up a book and leaves.

Figure 2: Qualitative results of the generated tree structure and sentences on the Charades Captions dataset.



(a) Sentence length distribution on the test set of Charades Captions.

(b) Sentence length distribution on the test set of MSR-VTT.

Figure 3: Distribution of average ground-truth sentence lengths on the test sets of Charades Captions (a) and MSR-VTT (b).

to 20 and the value of p on the MSR-VTT dataset is set to 10. As a result, the simple and complex subsets of Charades Captions contain 550 videos and 1,210 videos, respectively. The simple and complex subsets of MSR-VTT contain 2,005 videos and 985 videos, respectively.

We also calculated the average lengths of the ground-truth captions and the generated captions on the simple and complex subsets of Charades Captions and MSR-VTT, and the results are shown in Table 1.

Table 1: The average sentence lengths of ground-truth captions and the captions generated by "w/o tree" and "Ours" on the simple subset and complex subset of Charades Captions and MSR-VTT dataset.

Subset	sentence lengths		
	Ground-truth	w/o tree	Ours
Charades (all)	22.710	18.443	21.729
Charades (simple)	17.780	17.591	21.370
Charades (complex)	25.071	18.853	21.894
MSR-VTT (all)	9.315	7.942	7.266
MSR-VTT (simple)	7.630	7.586	6.959
MSR-VTT (complex)	12.746	8.668	7.890

Table 2: The average tree edit distance of different variants of our method on the Charades Captions dataset. Lower average edit distance is better.

model	average edit distance (↓)
w/o visual embedding	14.93
w/o reinforcement learning	15.05
sequence reward	14.76
ours	14.53

E More Results of Ablation Studies

To measure the significance of the results, we performed multiple 5 runs of the ablation studies on the Charades Captions dataset and report the mean ± standard deviation results and the results are shown in Table 3.

F Results of Image Captioning

To further validate the generalizability and scalability of the proposed method, we also conduct preliminary experiments of image captioning on MSCOCO [2] dataset. We use the output before

Table 3: The mean ± standard deviation of the ablation studies on Charades Captions dataset.

Model	B@4	M	R	C
w/o tree	17.68±0.20	18.65±0.14	40.20±0.09	23.50±0.13
w/o RL	17.08±0.26	18.19±0.10	38.97±0.12	22.53±0.13
w/o tree, RL	16.50±0.19	18.21±0.12	38.80±0.12	21.45±0.12
w/o visual embedding	16.90±0.20	18.19±0.12	39.45±0.14	21.87±0.10
sequence reward	18.50±0.24	19.20±0.13	40.32±0.10	23.41±0.14
Ours	18.87±0.25	19.38±0.20	40.50±0.13	24.21±0.12

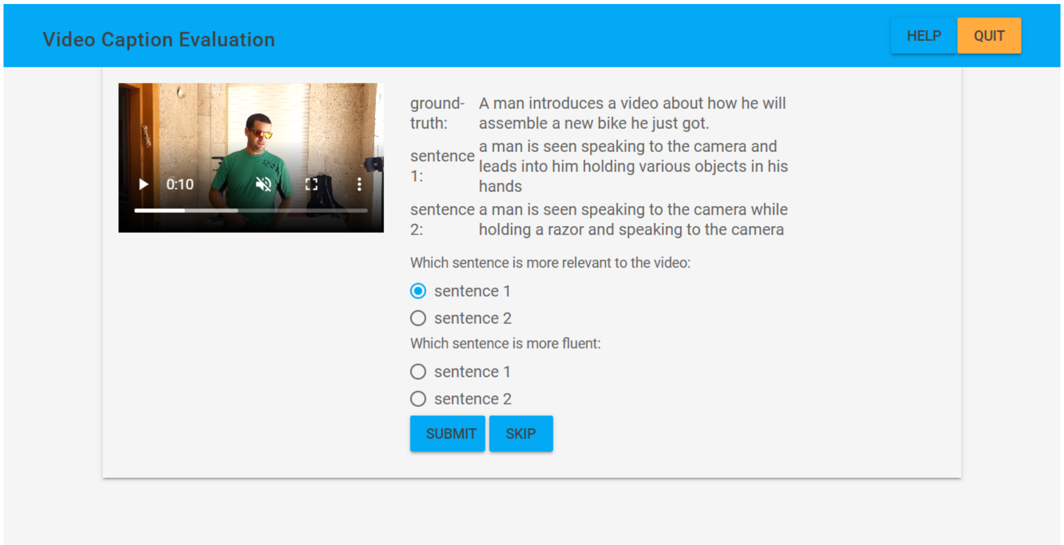
the last average pooling layer of ResNet-101 as the features of the images. From the results in Table 4, we observe that the proposed tree-structured decoding method can also be applied to the task of image captioning.

Table 4: Image captioning results on MSCOCO dataset.

Method	B@4	M	R	C
w/o tree	36.26	27.21	56.38	119.52
Ours	37.03	27.87	56.42	120.30

G Details About Human Evaluation

In this section, we illustrate more details of human evaluation. We recruited 10 annotators to carry out the human evaluation process. Each annotator is given the original video, a ground-truth sentence and two sentences generated by "Ours" and "w/o tree" and is asked to compare the relevancy and fluency of the generated sentences. The user interface for human evaluation is shown in Figure 4. To ensure the fairness of human evaluation, among the two sentences generated by "Ours" and "w/o tree", we randomly choose one sentence to be "sentence 1" in the user interface and the other sentence is "sentence 2".



ground-truth: A man introduces a video about how he will assemble a new bike he just got.

sentence 1: a man is seen speaking to the camera and leads into him holding various objects in his hands

sentence 2: a man is seen speaking to the camera while holding a razor and speaking to the camera

Which sentence is more relevant to the video:

● sentence 1
○ sentence 2

Which sentence is more fluent:

○ sentence 1
○ sentence 2

Figure 4: The graphical user interface for human evaluation.

Checklist

1. For all authors...
   (a) Do the main claims made in the abstract and introduction accurately reflect the paper's contributions and scope? [Yes]

(b) Did you describe the limitations of your work? [Yes]

(c) Did you discuss any potential negative societal impacts of your work? [Yes] Please refer to the supplementary material for potential negative societal impacts.

(d) Have you read the ethics review guidelines and ensured that your paper conforms to them? [Yes]

2. If you are including theoretical results...

   (a) Did you state the full set of assumptions of all theoretical results? [N/A]

   (b) Did you include complete proofs of all theoretical results? [N/A]

3. If you ran experiments...

   (a) Did you include the code, data, and instructions needed to reproduce the main experimental results (either in the supplemental material or as a URL)? [Yes]

   (b) Did you specify all the training details (e.g., data splits, hyperparameters, how they were chosen)? [Yes]

   (c) Did you report error bars (e.g., with respect to the random seed after running experiments multiple times)? [No]

   (d) Did you include the total amount of compute and the type of resources used (e.g., type of GPUs, internal cluster, or cloud provider)? [Yes]

4. If you are using existing assets (e.g., code, data, models) or curating/releasing new assets...

   (a) If your work uses existing assets, did you cite the creators? [Yes]

   (b) Did you mention the license of the assets? [No]

   (c) Did you include any new assets either in the supplemental material or as a URL? [No]

   (d) Did you discuss whether and how consent was obtained from people whose data you're using/curating? [N/A]

   (e) Did you discuss whether the data you are using/curating contains personally identifiable information or offensive content? [N/A]

5. If you used crowdsourcing or conducted research with human subjects...

   (a) Did you include the full text of instructions given to participants and screenshots, if applicable? [Yes] Please refer to the supplementary materials for details of human evaluation.

   (b) Did you describe any potential participant risks, with links to Institutional Review Board (IRB) approvals, if applicable? [N/A]

   (c) Did you include the estimated hourly wage paid to participants and the total amount spent on participant compensation? [Yes]

References

[1] K. Zhang and D. Shasha, "Simple fast algorithms for the editing distance between trees and related problems," *SIAM journal on computing*, vol. 18, no. 6, pp. 1245–1262, 1989.

[2] T.-Y. Lin, M. Maire, S. Belongie, J. Hays, P. Perona, D. Ramanan, P. Dollár, and C. L. Zitnick, "Microsoft coco: Common objects in context," in *European conference on computer vision*, pp. 740–755, Springer, 2014.