Data Augmentation for Low-Resource Dialogue Summarization

Yongtai Liu *
Department of Computer Science
Vanderbilt University
yongtai.liu@vanderbilt.edu

Joshua Maynez
Google Research
joshuahm@google.com

Gonçalo Simões
Google Research
gsimoes@google.com

Shashi Narayan
Google Research
shashinarayan@google.com

Abstract

We present *DADS*, a novel **D**ata **A**ugmentation technique for low-resource **D**ialogue **S**ummarization. Our method generates synthetic examples by replacing text sections from both the input dialogue and summary while preserving the augmented summary to correspond to a viable summary for the augmented dialogue. We utilize pretrained language models that produce highly likely dialogue alternatives while still being free to generate diverse alternatives. We applied our data augmentation method to the SAMSum dataset in low-resource scenarios, mimicking real-world problems such as chat, thread, and meeting summarization where large-scale supervised datasets with human-written summaries are scarce. Through both automatic and human evaluations, we show that DADS shows strong improvements for low-resource scenarios while generating topically diverse summaries without introducing additional hallucinations to the summaries.

1 Introduction

As many more language generation tasks are being explored, an outstanding issue is the lack of data available to train generation models. A question that follows is whether it is better to collect and annotate additional data in a particular domain or to generate synthetic data similar to the available data. Considering the elevated cost of collecting data, expertise needed or the difficulty of finding the data, research on data augmentation is warranted. Data augmentation (DA) encompasses methods used to inject additional knowledge into learning systems without explicitly collecting new data; the knowledge injected comes in the form of additional training examples assumed to be silver standard than the collected gold data.

In this paper, we propose an approach for **D**ata **A**ugmentation for **D**ialogue **S**ummarization, aka *DADS*, that creates semantically diverse synthetic examples from a low-resource dataset. Our method modifies both the input dialogue and the target summary while preserving the augmented summary to correspond to a viable summary for the augmented dialogue. First, DADS aligns pairs of utterances from the original dialogue to semantically similar sections in the summary; a large dialogue pretrained model, similar to Meena (Adiwardana et al., 2020), finetuned for dialogue reconstruction, is then used to replace the aligned utterances in the dialogue fabricating new dialogue. A new summary is then synthesized for the newly generated dialogue and the original summary, replacing the aligned sections in the summary using a state-of-the-art pretrained summarization model (Zhang et al., 2019).

Models trained with DADS augmented data produce significant performance gains in automated quality metrics for the SAMSum (Gliwa et al., 2019) dialogue summarization dataset in low-resource settings, displaying 25% improvement in Rouge when only 10 training examples are available. Gains in performance are present in other low-resource settings, such as 50 and 100 examples, but decrease as one would expect as more data is available. As the data augmentation process is inherently noisy, we further investigate whether generation models augmented with DADS are less faithful and analyze other aspects of language generation models such as diversity.

Our main contributions are as follows: (i) We introduce DADS, a novel approach for data augmentation for dialogue summarization for low-resource scenarios. (ii) We demonstrate that models trained with DADS augmented data are as faithful as models trained with the original data via human and automated faithfulness metrics. (iii) We found that the outputs generated by DADS augmented models are more diverse than the strong baselines we compare against.

*Work done during an internship at Google Research.

Findings of the Association for Computational Linguistics: NAACL 2022, pages 703 - 710
July 10-15, 2022

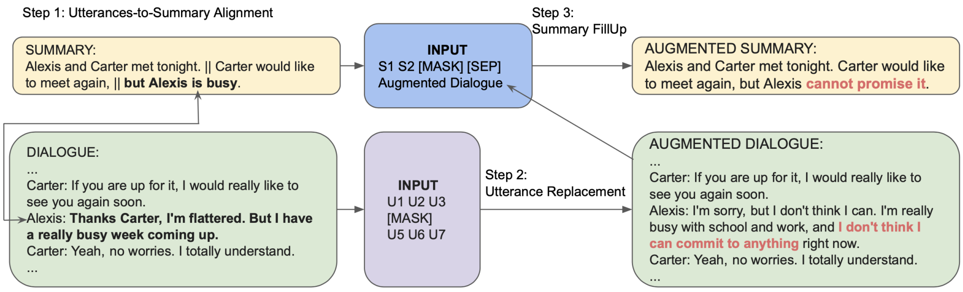

Figure 1: Data augmentation for dialogue summarization. We show how one utterance-summary section pair ($U4$ and $S3$) is aligned (Step 1), and replaced in the input (Step 2) and in the summary (Step 3), producing a new dialogue-summary pair. S's represent sections in the summary and U's represent utterances in the dialogue.

2 Related Work

There is extensive literature that explores DA for machine learning systems in computer vision (Shorten and Khoshgoftaar, 2019), natural language processing (Feng et al., 2021) and other areas. In NLP approaches vary from general-purpose techniques that generate slightly modified copies of existing data; Devries and Taylor (2017) augment examples with noise directly in feature space rather than input space, to domain-specific transformations to create synthetic data, whereas Sennrich et al. (2016) use back-translation to augment text sequences.

Many methods aim to incorporate external knowledge or harness systems and domains where more data is available, e.g., large language models. Recently, Lee et al. (2021) propose example extrapolation by training pretrained language models to extrapolate examples as a few-shot task.

Even though limited, research on data augmentation for language generation has had various approaches to data synthetization, such as corrupting the input text (Xie et al., 2017), the output text (Norouzi et al., 2016) or both (Zhang et al., 2020a). Notably, Schick and Schütze (2021) use pretrained language models and a diverse set of instructions to augment generation datasets in low-resource settings, rather than creating training examples. More recently, (Gunasekara et al., 2021) proposes an approach to augment dialogue systems when large amounts of in-domain data are available by training in-domain conversation generators.

3 Data Augmentation

We synthesize new training examples by augmenting both the dialogue and summary while ensuring that the generated summary is a good abstractive representation of the corresponding dialogue. The augmentation process is done in three steps: utterances-to-summary alignment, dialogue utterance replacement, and summary FillUp. Our workflow is shown in Figure 1 and described below.

Utterances-to-Summary Alignment With the goal of transforming the (dialogue d, summary s) example pairs into a new training example (dialogue d', summary s'), great care has to be taken to avoid them diverging and losing the 'summary-of' relation between the pair. To accomplish this, DADS keeps modifications limited to the aligned sections in the dialogue and summary. Firstly, we align summary spans with utterances in the input. For SAMSum dataset, summaries are comprised of 1 to 2 sentences. We expanded the granularity of augmentations to a sub-sentence level by splitting each sentence into clauses using an off-the-shelf NLP pipeline annotator spaCy (Honnibal and Montani, 2017).

Next, given the set of all summary clauses and dialogue utterances, we encode them into a shared space using the universal sentence encoder (Cer et al., 2018) and computed their cosine similarity. For each clause in the summary, we select the top 20% utterances with the highest similarity scores as our input pairs for augmentation. One (utterances, clause) pair will generate one augmented example.

Dialogue Utterance Replacement We use an auto-regressive encoder-decoder model, inspired by Meena (Adiwardana et al., 2020) and DialogGPT (Zhang et al., 2020b), but initialized from T5-11B (Raffel et al., 2020) and finetuned with a dialog reconstruction loss. The model is trained by randomly masking an utterance from an input example. We use the conversational dataset (SocialMedia), a large-scale, high-quality dialog dataset proposed by Meena (Adiwardana et al., 2020) for finetuning. We refer to this finetuned model as DIAL-REPL.

We use DIAL-REPL to generate synthetic alternatives for the selected utterances. Given the original dialogue, the corresponding position of the selected utterance is replaced by a [MASK] token, DIAL-REPL is asked to predict the masked utterance given the input dialogue, the summary and a prompt, as shown in step 2 of Figure 1. We used a standard prompt: "The following conversation is about: " followed by the summary and the dialogue. All the selected utterances are replaced one by one in an auto-regressive manner: previously generated utterances become part of the input of the next masked position.

Summary FillUp Lastly, we augment the summary by replacing the paired clause with a new one that is consistent with the augmented dialogue. We hope this procedure will fulfill two purposes, generate a more diverse set of summaries, avoiding downstream summarization models to memorize repetitive targets, and correct semantic deviations expected to happen during dialogue utterance replacement. We finetuned a large pretrained PEGASUS (Zhang et al., 2019) model for this particular task, to predict a masked sentence in the summary, given the input and summary as context.[1] To generate training data for this model, we converted examples from the CNN/DailyMail (Hermann et al., 2015) dataset by masking a sentence in the gold summary, prepending the masked summary with the input document, separated by a separator token and tasked the model with predicting the masked sentence, this is akin to the Gap Sentence Generation (Zhang et al., 2019) procedure. For summary augmentation, we mask the summary clause and prepend with the augmented dialogue as input and predict a new replacement clause using the Summary FillUp model.

We augment each annotated dialogue-summary (d, s) pair multiple times, drop duplicated outputs, and keep the rest as augmented examples.

4 Experimental Setup

4.1 Low-Resource Dialogue Summarization

We evaluate our method on the SAMSum dialogue summarization dataset (Gliwa et al., 2019), consisting of 14,732, 818 and 819 train, validation and test examples, respectively. To simulate the low-resource summarization setting, we randomly select 10, 50, and 100 annotated examples from the train split for augmentation, then select summarization model parameters with the validation split and report the summarization performance on test split. The inputs and targets were truncated to 1024 and 128.

4.2 Model Comparison

We compare DADS with two other strong baselines: a model trained with no augmented data and a model train using back-translation (Xie et al., 2019) to perturb data instead of language models. We refer to the first model as baseline and the second model as back-translation (Back-trans.) throughout the rest of the paper. In back-translation, we aim to replicate the process we propose of modifying both the dialogue and summary but with a limited semantically-preserving method.[2] For all models, we finetune a large PEGASUS model in two stages: first with the silver standard augmented examples, then we further finetune the model only with the gold examples. The checkpoints are selected using the SAMSum validation split and we report results on the test split. See Table 6 in Appendix for example predictions generated by three models.

4.3 Evaluation Metrics

Along with ROUGE F1 scores (Lin and Hovy, 2003), we report on standard metrics for Semantic Diversity and Faithfulness.

Semantic Diversity We measure word-level semantic diversity in generated summary with the ratio of the number of distinct n-grams and the number of total n-grams. A model that generates semantic-diverse summaries would have a higher proportion of distinct n-grams.

The spikiness of the topic distribution of summaries reflects topic-level diversity. A good summary that captures the main topic in the dialogue would have a sharp topic distribution. A lower entropy value corresponds to a sharper topic distribution. To quantify the spikiness for all the generated summaries, we take the average of the entropy values. Topic distributions are inferred from a MALLET LDA model (McCallum, 2002) trained on the summaries in the SAMSum train split.[3]

Faithfulness Following Maynez et al. (2020a), we report on textual entailment (Pasunuru and Bansal, 2018; Falke et al., 2019; Kryściński et al., 2019) for summary faithfulness evaluation.[4] We also assess faithfulness of generated summaries by human annotation.[5]

5 Results

Compared with the non-augmented baseline, which we call *NoAug*, we find that models trained with data augmentation generate better quality summaries in terms of ROUGE (see Table 1). More-

[1] See Appendix A for details about model architecture and parameter selection.

[2] See Appendix B for the back-translation model.

[3] See Appendix C for more details.

[4] See Appendix D for details about the entailment classifier.

[5] See Appendix E for more on the faithfulness assessment.

#Gold Ex	NoAug	Back-translation	DADS
10	25.5/08.3/21.3	28.5/9.6/23.4	**32.5/12.0/27.0**
50	39.8/16.8/32.7	**42.0**/17.9/34.1	41.9/**18.4/34.7**
100	43.0/19.2/35.4	43.2/19.0/35.4	**43.9/19.7/36.1**

Table 1: ROUGE scores (R1/R2/RL) for models trained on 10, 50, and 100 human annotated examples using different data augmentation approaches. For each task we train models in three different sampled sets and report the average score. For each model, the following evaluation and corresponding results are based on the one with the highest ROUGE score in the three runs.

Model	#Gold Ex	R1	R2	RL
NoAug	15	29.1	10.5	24.1
NoAug	20	32.4	**12.2**	26.6
DADS	10	**32.5**	12.0	**27.0**
NoAug	60	40.5	17.5	33.6
DADS	50	**41.9**	**18.4**	**34.7**
NoAug	110	43.6	**19.7**	35.9
DADS	100	**43.9**	**19.7**	**36.1**

Table 2: ROUGE scores for DADS models trained with 10, 50 100 number of annotated examples, compared with NoAug baseline models trained with 15, 20, 60 and 110 examples.

over, DADS outperforms the back-translation baseline in all three low resource settings: k = 10, 50, and 100.

For each setting and method, we investigated the amount of augmented data where downstream performance caps. For 10, 50 and 100 examples, back-translation achieves the best performance when 5, 50 and 100 times augmented data is added. For DADS, the best performance is achieved when the augmented data amount to 1, 25 and 25 times the gold data. We hypothesize this is because DADS augmented data contain more diverse and novel information than back-translation augmented examples.

Data Augmentation equivalence to Data Collection Trying to understand how data augmentation compares with data collection, we set out to find how many additional examples need to be collected to achieve the same performance as DADS augmentation. The result is shown in Table 2. We find that data augmentation when only 100 examples are available is equivalent to more than 10 additionally annotated examples in terms of Rouge-L.

Effect on Semantic Diversity In Table 3, we show the distinct n-gram proportions and average entropy values for summaries predicted from models trained with 50 annotated examples. Summaries generated by the model with DADS augmentation have the highest proportion of distinct n-grams and the lowest average topic distribution entropy (spikiest topic distribution), suggesting that DADS generates semantically diverse examples. The result also suggests that DADS improved the summarization model's ability to produce textural-diverse, topic-focused summaries.

Model	Distinct-n n=1	Distinct-n n=2	Avg. Entropy
NoAug	0.162	0.514	6.598
Back-trans.	0.160	0.502	6.604
DADS	**0.176**	**0.581**	**6.597**

Table 3: The number of distinct uni-grams and bi-grams divided by the number of total uni-grams and bi-grams, respectively, higher is better, and average topic distribution entropy, lower is better. All models were trained with 50 annotated examples.

Model	Entail.	Faithfulness	Agree.
Baseline	0.805	2.39	0.66
Back-trans.	0.796	2.41	0.70
DADS	**0.829**	**2.60**	**0.64**

Table 4: Faithfulness assessment (Entailment and Human evaluation) for models trained with 50 annotated examples. Following Durmus et al. (2020), agreement (Agree.) is computed by taking the percentage of the annotators that annotate the majority class for the given (dialogue, summary) pair.

Effect on Faithfulness We report the entailment score and the human evaluated faithfulness score in Table 4. We randomly selected 50 documents from the SAMSum test split and assessed the generated summaries from all 3 systems (NoAug, back-translation, and DADS) trained with 50 annotated examples. DADS has the highest Entailment score and faithfulness score. However, through the one-way ANOVA test ($p < 0.01$), we find that differences among all model pairs for both entailment and faithfulness are insignificant. This finding suggests that our augmentation approach does not introduce additional hallucinations into the system.

6 Conclusion

We introduced DADS, a new augmentation approach for dialogue summarization tasks. Under 100 annotated examples, the improvement brought from augmentation is roughly equivalent to 10 more annotated examples. Furthermore, we showed that DADS generates semantically diverse synthetic examples. Finally, through automatic and human evaluation, we showed that our augmentation approach does not introduce additional hallucinations to the summarization model. The methods described here are not particular to a type of dialogue summarization task and we leave for future research the application of similar methods to other dialogue summarization domains.

Ethical Considerations

The nature of text generation leads to multiple ethical considerations when applied to applications. The main failure mode is that the model can learn to mimic target properties in the training data that are not desirable.

Faithfulness and Factuality Since models create new text, there is the danger that they may neither be faithful to the source material nor factual. This can be exacerbated when the data itself has highly abstractive targets, which require the model to generate words not seen in the source material during training. This often leads the model to generate content inconsistent with the source material (Maynez et al., 2020b; Kryscinski et al., 2020; Gabriel et al., 2021).

Trustworthy Data If the data itself is not trustworthy (comes from suspect or malicious sources), the model itself will naturally become untrustworthy as it will ultimately learn the language and topics of the training data. For instance, if the training data is about Obama birther conspiracies, and the model is asked to generate information about the early life of Obama, there is a risk that such false claims will be predicted by the model.

Bias in Data Similarly, biases in the data around gender, race, etc., risk being propagated in the model predictions, which is common for most NLP tasks. This is especially true when the models are trained from non-contemporary data that do not represent current norms and practices (Blodgett et al., 2020).

The above considerations are non-malicious, in that the model is merely learning to behave as its underlying source material. If users of such models are not aware of these issues and do not account for them, e.g., with better data selection, evaluation, etc., then the generated text can be damaging.

Generation models can also be misused in malicious ways. These include generating fake news, spam, and other text meant to mislead large parts of the general population.

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A Summary FillUp Model

Summary FillUp is finetuned from **PEGASUS$_{\textbf{LARGE}}$** public checkpoint. The model had L = 16, H = 1024, F = 4096, A = 16 (568M parameters), where L denotes the number of layers for encoder and decoder Transformer blocks, H for the hidden size, F for the feed-forward layer size and A for the number of self-attention heads. All finetuning experiments are done with a batch size of 8. For optimization, we used Adafactor (Shazeer and Stern, 2018) with square root learning rate decay with a learning rate of 0.0001 and a dropout rate of 0.01. The model was decoded with a beam size of 8 and a length penalty of 0.6.

B Back-translation

For back-translation, we adopted Xie et al. (2019)'s back-translation implementation to increase diversity. As reported by the authors, the models used were trained in WMT'14 English-French (in both directions). The authors used the hyperparameter *sampling_temp* to control the diversity and quality of the back-translation. We found that setting it to 0.5 yielded the best augmented examples.

C LDA model

Mallet LDA models were trained with all the 14,732 human-annotated summaries in the SAMSum train split. We varied the number of topics from 2 to 340, with a step of 2, and selected models with 100, 200, and 300 topics. The corresponding coherence scores are 0.524, 0.587, and 0.614. Given summaries generated by models trained with DADS and two baselines, the average topic distribution entropy values calculated from the three LDA models are shown in Table 5. DADS has the lowest average entropy in all three settings.

Model	t=100	t=200	t=300
Baseline	6.598	7.583	8.163
Back-trans.	6.604	7.592	8.172
DADS	**6.597**	**7.583**	**8.162**

Table 5: Average entropy values for Baseline, Back-translation and DADS calculated from three LDA models with number of topics t = 100, 200, and 300.

D Entailment Classifier

Given summary and dialogue, the entailment classifier outputs the probability of the summary entailing the dialogue. We finetuned a transformer-based model, initialized with a pretrained BERT-Large checkpoint (Devlin et al., 2018), on the Multi-NLI dataset (Williams et al., 2017).

E Faithfulness Assessment

We ran a small annotation task with three raters, all proficient in English and NLP researchers, who were asked to read the dialogue carefully and then grade the accompanying summary on a scale of 1-4 (fully unfaithful, somewhat unfaithful, somewhat faithful, and fully faithful). A summary is "fully faithful" if all of its content is fully supported or can be inferred from the document.

Gold	Emma was late and missed Andy's song, but she still had fun.
Dialogue	Emma: Hey it was fun right? George: Yes, certainly.... but why you came so late. you missed andy's song. Emma: I know :(but still i had a lot of fun. George: yes.. will plan again Emma: yes pleaseeeeee
No Aug. R1/R2/RL	George will plan again for Emma. 16.2 / 9.8 / 16.2
Back Trans. R1/R2/RL	George will come to Emma's place again. 10.3 / 0.0 / 10.3
DADS R1/R2/RL	Emma came late but still had a lot of fun. George will plan again. 52.2 / 24.0 / 47.8
Gold	Robert wants Fred to send him the address of the music shop as he needs to buy guitar cable.
Dialogue	Robert: Hey give me the address of this music shop you mentioned before Robert: I have to buy guitar cable Fred: < file_other > Fred: Catch it on google maps Robert: thx m8 Fred: ur welcome
No Aug. R1/R2/RL	Robert has to buy guitar cable and Fred has to Catch it on google maps. 40.9 / 29.8 / 40.9
Back Trans. R1/R2/RL	Robert and Fred will meet on google maps. 15.4 / 9.8 / 15.4
DADS R1/R2/RL	Robert wants Fred to give him the address of this music shop. 37.2 / 22.2 / 32.6
Gold	Heidi wants Noah to take items away from the balcony and close all the windows.
Dialogue	Heidi: Could you take the things away from the balcony? I forgot about them and it's going to rain today. Noah: I'll do it as soon as I am back home. Heidi: And close all the windows in case of a storm. Noah: of course
No Aug. R1/R2/RL	Noah will take the things away from Heidi's balcony. 21.3 / 15.4 / 21.3
Back Trans. R1/R2/RL	Noah will take the things away from Heidi. 21.7 / 15.7 / 21.7
DADS R1/R2/RL	Noah will take the things away from the balcony as soon as he is back home. 34.6 / 27.1 / 34.6

Table 6: Dialogue summarization examples: the dialogue, its gold summary, and the model generated summaries. We also present the [ROUGE-1, ROUGE-2, ROUGE-L] F1 scores relative to the reference dialogue. The models are trained using 50 annotated examples in SAMSum, with No Augmentation (No Aug.), augmented by Back Translation (Back Trans.), and DADS.