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Learning to Prioritize: Precision-Driven Sentence Filtering for Long Text Summarization

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Abstract

Neural text summarization has shown great potential in recent years. However, current state-of-the-art summarization models are limited by their maximum input length, posing a challenge to summarizing longer texts comprehensively. As part of a layered summarization architecture, we introduce PURETEXT, a simple yet effective pre-processing layer that removes low-quality sentences in articles to improve existing summarization models. When evaluated on popular datasets like WikiHow and Reddit TIFU, we show up to 3.84 and 8.57 point ROUGE-1 absolute improvement on the full test set and the long article subset, respectively, for state-of-the-art summarization models such as BERTSUM and BART. Our approach provides downstream models with higher-quality sentences for summarization, improving overall model performance, especially on long text articles.

Keywords: text summarization, machine learning, natural language processing

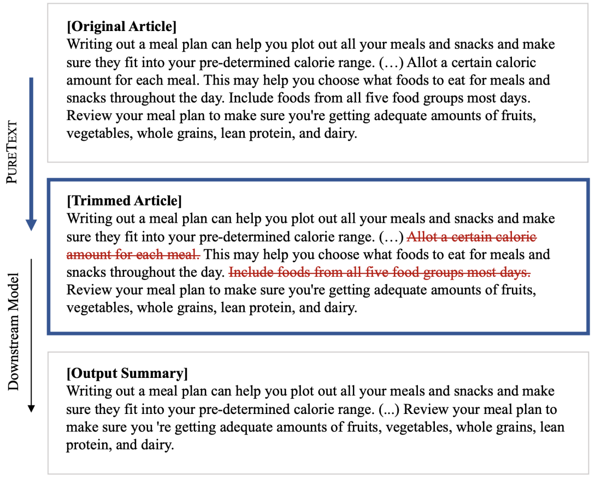
1. Introduction

Neural summarization models have evolved quickly over time, successfully tackling increasingly complex problems relating to natural language (Zhong et al., 2020; Zhou et al., 2018; Zhang et al., 2019; Xu et al., 2020). One key problem that has plagued state-of-the-art summarization models is their maximum input length (Liu, 2019; Lewis et al., 2020). Although recent work has progressed towards addressing this issue for Transformer-based models (Beltagy et al., 2020; Zhou et al., 2021; Choromanski et al., 2021), not as much attention has been paid specifically to long text summarization.

Summarization models such as BERTSUM (Liu, 2019) and BART (Lewis et al., 2020) either truncate or cannot handle articles longer than the maximum input length. Truncation may leave out critical parts of the text, leading to an incomplete summary.

For datasets where LEAD-3 forms a decent baseline (Nallapati et al., 2016; Narayan et al., 2018), truncating an article's ending may not greatly affect summarization. While this may be true for news summarization datasets in which story highlights tend to appear at the start (Hermann et al., 2015; Nallapati et al., 2016; Narayan et al., 2018), other datasets such as WikiHow (Koupaee and Wang, 2018) and Reddit TIFU (Kim et al., 2019) typically do not follow the same journalistic structure. WikiHow instructional texts contain key steps evenly dispersed throughout the article, and Reddit stories tend to follow a narrative arc where the climax is toward the end of the passage.

One simple solution to truncation is to omit the middle section of an article instead (Sun et al., 2019). However, this method, along with similar approaches, is a heuristic band-aid solution that can potentially be improved upon with a more versatile model.



[Original Article]
Writing out a meal plan can help you plot out all your meals and snacks and make sure they fit into your pre-determined calorie range. (…) Allot a certain caloric amount for each meal. This may help you choose what foods to eat for meals and snacks throughout the day. Include foods from all five food groups most days. Review your meal plan to make sure you're getting adequate amounts of fruits, vegetables, whole grains, lean protein, and dairy.

[Trimmed Article]
Writing out a meal plan can help you plot out all your meals and snacks and make sure they fit into your pre-determined calorie range. (…) ~~Allot a certain caloric amount for each meal.~~ This may help you choose what foods to eat for meals and snacks throughout the day. ~~Include foods from all five food groups most days.~~ Review your meal plan to make sure you're getting adequate amounts of fruits, vegetables, whole grains, lean protein, and dairy.

[Output Summary]
Writing out a meal plan can help you plot out all your meals and snacks and make sure they fit into your pre-determined calorie range. (...) Review your meal plan to make sure you 're getting adequate amounts of fruits, vegetables, whole grains, lean protein, and dairy.

Figure 1: A WikiHow instructional article on "How to Lose Weight Without Exercising." Rather than feeding the article directly to a model for summarization, we first filter high-quality sentences using a weakly-supervised layer that we call PURETEXT.

While existing works show promising results for long text summarization (Beltagy et al., 2020; Xu et al., 2018), they require extensive computational resources to run and and are not easily integrated with other existing state-of-the-art models. For example, a user with a summarization model fine-tuned for a specific task cannot simply just replace their current model without sacrificing performance. PureText, however, is a general approach that can be applied as a preprocessing layer to any model. This filtering layer serves as a screen for high-quality sentences before continuing to summarize with a state-of-the-art summarization model that produces the final refined summary. Although other multi-step processes have been attempted in the past for long text summarization, they often have specific applications like in low resource settings (Bajaj et al., 2021) or documents with an identifiable discourse structure (Gidiotis and Tsoumakas, 2020). Several two-step summarization methods employ an extractive-then-abstractive approach; however, these systems are intended to stand alone rather than augment any existing model (Wang et al., 2017; Chen and Bansal, 2018; Lebanoff et al., 2019). Other methods require modifying the training task of the downstream model (Gehrmann et al., 2018). Our layered summarization architecture allows for versatility, as the filtering layer can be used to augment many existing downstream summarization models without modifications.

Our filtering layer takes inspiration from dense sentence retrieval, (Zhong et al., 2020; Zhang et al., 2019) prioritizing important sentences for summarization. Critically, we take a weakly-supervised learning approach in which we train a BERT-based model to rank the importance of sentences based on their individual ROUGE scores when compared with the gold summary. We then filter up to 80% of an article's sentences before feeding it to a downstream summarization model. Figure 1 provides an example of our full pipeline on a single article.

We experiment on the WikiHow and Reddit TIFU datasets and observe that our model removes sentences irrelevant for summarization, improving on previous state-of-the-art results.

To summarize our contributions:

- We propose a model-agnostic weakly supervised learning objective using text similarity for the purpose of sentence filtering.
- We explore a layered-architecture approach in text summarization and introduce a versatile, lightweight filtering layer that we name PURE-TEXT for filtering out low-quality sentences.
- We test our approach on BERTSUM and BART and find up to 3.84 and 8.57 point ROUGE-1 improvement on the WikiHow and Reddit full datasets and long article subsets, respectively.

2. Methodology

We fine-tune a BERT-based model [1] to classify sentences as either "important" or "unimportant" using a sentence's ROUGE-1 F_1 score to generate its label. Since sentences are a subunit of an article with self containing grammar, they a natural choice for filtration to produce a more concise article. We assume that a sentence's ROUGE-1 F_1 score is strongly correlated with its degree of importance for summarization, and as such, ROUGE-1 F_1 is the final metric used for summary evaluation. Subsequently, we select the best subset of sentences that do not exceed the downstream model token limit and then feed the filtered article to a downstream model for summarization. This can allow downstream models to make use of the most important sentences in an article and produce a further refined summary. We further experiment to see whether additional filtration beyond the downstream model input limit helps further improve summary quality. We hypothesize that additional filtration provides more help to a not fine-tuned model by narrowing the scope of sentences considered important.

2.1. Classification

To supervise the training of the classifier, we create silver labels consisting of either "important" or "unimportant" for each sentence. To determine the importance of each sentence in the article, we utilize ROUGE due to its lightweight text similarity measure. Specifically, for a given sentence, we first calculate its ROUGE-1 F_1 similarity score to the ground-truth summary. We then label a percentage of the sentences with the highest score as "important" and the rest as "unimportant". After varying the ratio of "important" to "unimportant" sentences in increments of 10%, we find that labeling sentences with a score above the median [2] as "important" and sentences with a score below the median as "unimportant" works best.

We tested ROUGE-1 precision and recall as alternative labelling metrics to F_1, but found that ROUGE-1 F_1 produced the best scoring summaries. Since extractive models can maximize recall by using the entire article as a summary, F_1 provides a balance by taking the harmonic mean of recall and precision. Thus, we take a precision-driven approach to maximize the final ROUGE-1 F_1 scores.

Once we generate the labels for each of the sentences in our training set, we train our BERT-based classifier and then use it to predict the importance of sentences in our test set.

2.2. Sentence Selection

After the classifier predicts each sentence as either "important" or "unimportant," the sentences of each article are ranked by their respective class probabilities of being "important." Since the training objective of the model is to maximize the ROUGE-1 F_1 score, we define the reward R_i of a given sentence based on its probability of falling into the "important" class as assigned by the model.

Next, we frame the problem of finding the set of sentences that produce the highest cumulative reward,

[1] We use the BERT Sequence Classification model from Hugging Face for 5 epochs using early stopping, learning rate = $1 * 10^{-6}$, weight decay = 0.005, warmup steps = 0, and batch size = 32. Checkpoints are saved every 250 steps and we choose the model checkpoint with the lowest validation loss. For all other hyperparameters, we use the default provided by Hugging Face Trainer. The model is trained on 3 NVIDIA Titan X Pascal + 1 GeForce GTX Titan X GPUs for 10,000 steps each, elapsing 10 hours on average.

[2] We calculate the median score for each article to assign labels for each sentence within it. This way, we ensure that each article consists of an equal number of "important" and "unimportant" sentences.

$R_1/R_2/R_L$	WikiHow$_{full}$		Reddit TIFU$_{full}$	
Method	BertSum	Bart	BertSum	Bart
Baseline	30.70/8.77/28.54	23.30/5.74/15.14	20.88/5.14/17.18	13.10/2.30/9.17
Random$_{50}$	28.95/7.64/26.86	24.43/5.81/15.39	19.35/4.10/15.86	14.78/2.59/10.11
Head Only	28.82/7.78/26.76	21.85/4.94/14.11	19.52/4.27/15.99	12.40/1.99/8.71
Tail Only	28.85/7.74/26.76	21.83/4.93/14.07	19.49/4.27/15.98	12.39/1.99/8.72
Head + Tail	28.96/7.79/26.87	21.88/4.96/14.09	19.61/4.30/16.07	12.40/1.99/8.72
PureText$_{default}$	**31.53/9.10/29.30**	23.47/5.81/15.22	20.98/5.25/17.30	13.18/2.33/9.21
PureText$_{20}$	**31.53**/9.07/29.27	23.63/5.86/15.24	**21.03/5.32/17.33**	13.26/2.36/9.26
PureText$_{80}$	29.52/7.82/27.19	**27.14/7.05/16.62**	19.32/4.42/15.60	**15.85/3.17/10.77**

Table 1: Rouge F_1 scores produced by downstream summarization models on the full test sets when we apply our sentence filtering approach, labeling 50% of sentences as "important". We apply additional filtration, denoted by PureText$_{default}$ (filtering to the maximum input limit) or PureText$_x$ (filtering to $x\%$ below the maximum input limit, e.g. PureText$_{20}$ would mean filtering to 410 tokens rather than 512 for BertSum). We compare to baselines without filtering, 50% random filtering, head only (first 510 tokens), tail only (last 510 tokens), and head+tail (first 128 tokens + last 382 tokens) (Sun et al., 2019). The results we present are statistically significant with $\rho < 0.05$.

$R_1/R_2/R_L$	WikiHow$_{subset}$		Reddit TIFU$_{subset}$	
Method	BertSum	Bart	BertSum	Bart
Baseline	30.12/8.07/28.23	22.46/4.35/14.62	20.52/3.91/16.52	11.26/1.13/8.27
Random$_{50}$	30.25/8.01/28.26	23.44/4.73/14.70	20.26/3.68/16.43	13.06/1.52/9.12
PureText$_{default}$	32.33/**8.95**/**30.25**	23.55/4.85/15.21	20.98/**5.25**/**17.30**	12.64/1.59/8.95
PureText$_{20}$	**32.40**/8.85/30.25	24.39/5.10/15.23	**21.20**/4.65/17.23	14.12/1.99/9.70
PureText$_{80}$	30.00/7.36/27.78	**31.03/7.11/17.24**	19.90/3.83/15.82	**17.39/2.96/11.36**

Table 2: Rouge F_1 scores produced by downstream summarization models on the subset of long articles from the test sets. Other variables are consistent with those in Table 1.

$\sum R_i$, without exceeding the given token limit L [3] of a downstream model in the context of the 0-1 Knapsack algorithm. Each sentence is weighted according to its number of tokens. Finally, we feed the best set of sentences, which we call the "trimmed article," to a downstream model for summarization.

2.3. Sentence Filtration

The 0-1 Knapsack algorithm finds the most important sentences up to the token limit. At the same time, we hypothesize that filtering additional low-quality sentences can benefit the downstream summarization model by providing a better signal. We grid-search from 0 to 80% additional filtering below the maximum input token limit L to determine the best percentage.

3. Resources

We choose to test our method on the WikiHow and Reddit TIFU datasets due to their non-journalistic structure. We also examine the results on the subset of long text articles within these datasets since that is where we aim to see the most improvement. Additionally, we select downstream models with the ability to analyze texts at a finer granularity than the sentence level so that the final outputted summary can be further refined beyond our best-selected sentences.

WikiHow (Koupaee and Wang, 2018) is an instructional text dataset. It contains 180K step-by-step tutorials with a summarizing sentence and a detailed paragraph elaboration for each instruction.

Reddit TIFU (Kim et al., 2019) is a summarization dataset. We use only the TIFU-long subset, which contains 40K posts from the TIFU subreddit. Each post contains a "TL;DR" as the summary.

BertSum (Liu, 2019) is a fine-tuned Bert model for extractive summarization with the ability to perform trigram blocking.

Bart (Lewis et al., 2020) is an autoencoder for pretraining sequence-to-sequence models using bidirectional and auto-regressive transformers. We use the standard, non-fine-tuned, version of Bart to show that our sentence filtering approach does not require downstream models to be fine-tuned.

[3] L is 512 for BertSum and 1024 for Bart.

[Ground Truth Summary]
Count calories. Write yourself a meal plan. Eat a balanced diet. Snack healthy. Choose healthier cooking techniques. Drink adequate amounts of fluids. Ditch alcohol and sugary beverages.

[Output Summary w/ PURETEXT]
Writing out a meal plan can help you plot out all your meals and snacks and make sure they fit into your predetermined calorie range. Figure out how many calories you can cut from your daily diet by first calculating the number of calories you should take in each day. Review your meal plan to make sure you're getting adequate amounts of fruits, vegetables, whole grains, lean protein, and dairy.

[Output Summary w/o PURETEXT]
Writing out a meal plan can help you plot out all your meals and snacks and make sure they fit into your predetermined calorie range. Figure out how many calories you can cut from your daily diet by first calculating the number of calories you should take in each day. Weight loss programs usually require you to modify your total calorie intake.

Figure 2: An example of a summary generated with and without PURETEXT as compared with the Ground Truth Summary, using the same article from Figure 1. The summary produced without PURETEXT includes an irrelevant sentence, while the output summary with PURETEXT includes a relevant sentence that would have otherwise been truncated.

4. Results

We evaluate PURETEXT's performance on WikiHow and Reddit using BERTSUM and BART. Notably, we see strong relative improvements in downstream summary quality for BERTSUM and BART with PURETEXT. These results are compared with five baselines: summarization without PURETEXT, random, head only, tail only, and head + tail. Summarization without PURETEXT feeds article directly to the downstream summarization model without sentence filtering. The random baseline removes each sentence at a 50% chance. The head only baseline uses the first 510 tokens, the tail only baseline uses the last 510 tokens, and the head + tail baseline uses a combination of the first 128 tokens and the last 382 tokens (Sun et al., 2019).

4.1. Full Dataset

We present the results from evaluating PURETEXT with multiple levels of additional filtration on the full WikiHow and Reddit TIFU datasets in Table 1. Note that we also experimented with the CNNDM and XSum news datasets and found statistically insignificant results. We find that BERTSUM and BART improve up to 0.83 and 3.84 points in absolute ROUGE-1 F_1, respectively, when compared to the baseline summaries.

Since out-of-the-box BART is not fine-tuned for a specific dataset, we must provide additional support to guide the model. To provide better signal, we apply additional filtering to further remove lower quality sentences. For fine-tuned BERTSUM, however, we hypothesize that it learns to utilize context from lower quality sentences to improve the overall summary quality with less filtration.

4.2. Long Article Subset

To test the ability of PURETEXT to improve summarization on longer articles, we manually construct a subset of each dataset containing only articles that exceed the downstream model input limit. Quantitatively, Table 2 shows PURETEXT improves on the long article subset by a factor of 3 greater than the full dataset, with up to a 2.28 and 8.57 point improvement on BERTSUM and BART respectively. These improvements provide statistically significant evidence that PURETEXT improves long text summarization. We reason that this is due to PURETEXT being a better guide for each model than their default handling of longer articles. We also perform ad hoc qualitative analysis. Figure 2 shows a qualitative example that that PURETEXT enables downstream models to summarize with better context, as opposed to the default arbitrary truncation.

5. Conclusion

We introduce a novel, precision-driven sentence filtering layer called PURETEXT. We utilize a BERT-based model trained with weakly-supervised learning to distinguish high-quality sentences, which are then passed to a state-of-the-art downstream summarization model. Our results show that PURETEXT can greatly improve upon downstream model baselines for multiple datasets and models. It excels at improving summarization for long articles. We hypothesize that PURETEXT is particularly effective on long articles because truncation of these articles often results in removing important sentences. This suggests that it is most applicable to datasets similar to WikiHow and Reddit, where key sentences are evenly distributed throughout each article. Conversely, journalistic articles tend to have important sentences concentrated towards the beginning of the article, making it less effective. Unlike the extract-then-generate paradigm, our approach proposes a lightweight layer that we can prepend to existing summarization models as part of a layered-architecture approach. This allows our approach to generalize to a variety of existing summarization models. We encourage future work to expand on the comprehensiveness of our study and to continue exploring the dataset- and model-agnostic nature of such a sentence filtering layer for downstream summarization.

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