

# But Can You Do This?

## Evaluating a Standard Image Caption Generator's Descriptions of Images Taken by People Who Are Blind

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### **Abstract**

While advances in automatic caption generation for images continue to rapidly improve, analysing and examining the performances of these models on real-world applications is not common. People who are blind or have visual impairments heavily rely on image captioning services in their day-to-day lives and are directly affected by this. In this paper, a standard image caption generator (an encoder-decoder model with attention) is implemented using VizWiz-Captions, a domain-specific dataset. While its performance was poor, obstacles within the dataset, model, and task are identified and discussed. Image quality, high variation of captions, annotator reliability, and domain-specific necessities are all hurdles that are often overlooked. In order to ensure that advancements in research are applied in the real-world to help people, we must continue to be more critical of models that are already deemed successful and consider how they can be further improved for domain-specific tasks.

### **1 Introduction**

Image caption generation continues to be a pertinent task within both the computer vision and the natural language processing (NLP) research fields. However, it is important for researchers to also consider how advancements in this field can and will affect users in the real world. Developing models that will be able to effectively and efficiently assist users with visual impairments in their day-to-day lives is a challenge in the field to this day. Models that are considered to have a high performance in automatically generating captions will not necessarily perform well in a domain-specific task. Captions for the visually impaired must be detailed yet concise and prioritise the objects of interest within the image. Another factor that could affect a model's performance would be the quality

of the images that are typically associated with caption generation for this task. It is not uncommon for images to be in the wrong orientation, unfocused, and out of frame. While any improvement in image captioning is still a step forward, critically examining applications of these models in situations that are not as contrived is extremely important.

In this project, the VizWiz dataset presented by Gurari et al. (2020), specifically created to represent the blind and visually-impaired community, is used to train an encoder-decoder model with attention to examine how a standard image captioning model will perform in generating captions for the visually impaired. Evaluating the neural image caption generator with visual attention presented by Xu et al. (2015) through a domain-specific lens is important for the community being affected but also will have research-related contributions. Choosing to assess a model in this way presents nuances that are sometimes overlooked when implementing these models. It will also shed light on how humans would approach a task and eventually the possibility of replicating said modus operandi or intuition in a model. The problem of the gap between the two modalities—image and text—presented in Bernardi et al. (2016) is also discussed. As expected, this problem negatively affects the model's performance and is shown to be further exacerbated because of the difficulty to ground the captions with their respective images.

The following sections are organised as follows. Section 2 introduces image caption generation and the models and attention mechanism that precede what was implemented for this paper. In Section 3, the VizWiz dataset and specifics of the model implementation are given. The results are presented in Section 4. Section 5 discusses the results. The conclusion and future work are stated in Section 6 and is followed by the references used for this paper.

## 2 Related Work

Automatic description generation from images has been a challenging task that both the computer vision and natural language processing communities have taken an interest in. [Bernardi et al. \(2016\)](#) surveys the current approaches to this task and classifies these approaches through how they conceptualise the problem—either a generation problem, a retrieval from a visual space problem, or a retrieval from a multimodal space problem. All three approaches have their advantages and disadvantages. The first two approaches choose to rely more heavily on one modality (visual or textual) to base the predictions for generating captions while the third approach attempts to combine both representations to make the final image description. The implementation in this paper is the third approach. This approach attempts to address the semantic gap or mapping problem between language and image representations through the attentional component. The attention mechanism allows us to see visualizations of which regions in an image are salient and where the model is “looking” when generating each word in the caption.

The model implemented in this paper is a combination of proposed methods from two different, but related, research areas—image captioning and machine translation. [Vinyals et al. \(2014\)](#)’s seminal paper *Show and Tell* presents a neural image caption generator (NIC) that uses a vision convolutional neural network (CNN). The CNN encodes images into representations in a fixed dimension for the decoder. These representations are typically richer compared to a recurrent neural network (RNN) encoder. The encoder’s output is then passed to the decoder which is a language-generating RNN—an LSTM-based sentence generator. Their model demonstrates that this approach significantly improves both accuracy and fluency when generating captions. The second method is a neural machine translation with an attention mechanism proposed by [Bahdanau et al. \(2014\)](#). Attention allows the model to look for parts in the source sentence that would be most relevant in predicting the target word. The flexibility of alignment between the source and target sentences introduced through attention allows for better translations, especially between languages that have syntactical differences.

The combination of NIC and an attention mechanism resulted in the model implemented by [Xu](#)

[et al. \(2015\)](#)—a neural image caption generator with visual attention. The encoder uses low-level representations which prioritises salient features of an image. The attention component adds “an extra layer of interpretability to the output of the model” ([Xu et al., 2015](#)) and the alignments learned by the model correspond very well with human intuition. The motivations and intuitions of choosing to use the model implemented by [Xu et al. \(2015\)](#) for this domain-specific task is discussed in Section 3.

## 3 Dataset & Methodology

### 3.1 VizWiz Dataset

The domain-specific dataset used for this project was the VizWiz dataset<sup>1</sup>. It is comprised of 39,181 images taken by people who are either blind or visually impaired. The images of the dataset come from a mobile phone application made to support real-world users through their visual description service. Users take a picture, record a spoken question, and are then connected with people that could assist them. The VizWiz dataset has also been developed for various computer vision tasks, all related and extremely useful for the visually impaired community: image captioning, image quality assessment, visual question answering (VQA), answer-difference reasoning, vision skills for VQA, and visual privacy recognition. The VizWiz dataset is “a valuable foundation for designing more generalized computer vision algorithms that meet the large diversity of needs for real end users.” ([Gurari et al., 2020](#))

#### 3.1.1 VizWiz-Captions Dataset

For this project, the VizWiz-Captions dataset<sup>2</sup> was used. Each image is paired with 5 human-made captions collected through crowdsourcing via Amazon Mechanical Turk. Due to GPU limitations and consciousness of memory usage, only the training dataset was used. The training dataset originally had 23,141 images and 117,155 captions. After examining some of the metadata included in the dataset, a filtering process was conducted. If an image was considered to be spam (*is\_rejected*) or considered to have quality issues by annotators (*is\_precanned*, if True had “Quality issues are too severe to recognize visual content.” as its caption), they were filtered out of the dataset. Images with

<sup>1</sup><https://vizwiz.org/>

<sup>2</sup><https://vizwiz.org/tasks-and-datasets/image-captioning/>

the characteristic of having text were kept since text is one of the main reasons why someone who is visually impaired would need assistance. After filtering, there were 14,790 images left and the model implementation was done with a 60/20/20 train, validation, test split (8,874 train, 2,958 validation, and 2,958 test).

### 3.1.2 Annotator Reliability & Ethical Considerations

Although it is incredibly important to collect human-made captions for any text generation task, the process and its output also present some challenges and factors that must be considered. While it is greatly advantageous for a model to learn from human-made captions, humans are not perfect and also make mistakes. Crowdsourcing allows researchers to reach a larger, more widespread and diverse demographic but it also makes it much more difficult to oversee and guide annotators to ensure that the captions being made are of the best quality. The instructions provided to annotators presented in Gurari et al. (2020), while understandably so given the conditions of the annotation process, were very concise and left space for restrictions on the annotators that would affect the dataset and future model implementations.

Examples of instructions that could lead to problems when training models are: “Include at least eight words.”, “Describe all parts of the image that may be important to a person who is blind.”, and “If text is in the image, and is important, then you can summarize what it says. DO NOT use all the specific phrases that you see in the image as your description of the image.” (Gurari et al., 2020) If an annotator was able to effectively describe an image with four words (e.g. “Can of mushroom soup.”), they are then required to add additional information that might not be useful or necessary. The second instruction can also be interpreted as subjective and what one annotator thinks is useful information for a person who is blind, another annotator might not think similarly. Finally, the third instruction requiring a summarization of text that appears in an image rather than providing a word-for-word description makes it extremely difficult to ground any generated caption for a model. Although text summarization would be useful for this real-world task, it is a completely different task that is overlooked when training an image caption generator.

Since annotators were also found through crowd-

sourcing, annotator reliability could possibly be a point of contention. Not only are the annotators’ backgrounds unknown, they are also inconsistent. In an ideal world, it would have been better to have real-world users with high ratings from the mobile application to come in and annotate images as they have domain-specific knowledge and skills. Ethical concerns may also affect the quality of work annotators submit. It is extremely important to acknowledge the absolutely dismal wages provided to annotators through Amazon Mechanical Turk. (Hara et al., 2018) The low wages and absence of work benefits can also affect the care and quality of the captions made by annotators. With these considerations, an example is provided in Figure 1 of how varied and inconsistent the quality and structure of captions can be within the dataset. The variation in complexity and length is quite large and can be argued to be either advantageous or disadvantageous for a model when training.



- A1: a black bottle with red and black label
- A2: A bottle of hot sauce is full to the top.
- A3: A bottle of brown liquid with a red and black label.
- A4: Bottle of hot sauce sitting on what looks to be a pink pillow,
- A5: A clear plastic bottle that is full of a green/brown colored liquid and has a red and black label with the word "HOT" on it and some pictures of palm trees.

Figure 1: An image from the VizWiz-Captions dataset and 5 captions from 5 different annotators—all varying in length, complexity, priority, and specificity.

### 3.2 Model Architecture

The model implemented was an encoder-decoder with an attention mechanism. The PyTorch Tutorial to Image Captioning by Sagar Vinodababu<sup>3</sup> was followed and the implementation included an encoder that was pretrained on ResNet. The encoder is responsible for taking the images as input and transforming it into smaller representations. It returns a “state” that is fed into the decoder. The decoder is then responsible for interpreting the output of the encoder. It also calculates the attention weights for the image and its output is the generated caption.

Creating low-level representations when passed through the encoder seemed like a good approach for this task since a lot of images in the dataset only

<sup>3</sup><https://github.com/sgrvinod/a-PyTorch-Tutorial-to-Image-Captioning#training>

have one object as the focal point and sometimes this object is only partially shown in the image. A lower-level representation or a representation that is closer to what the image actually looks like would be very helpful rather than having a representation that is an average of everything in the picture. This approach is be called the top-down approach—contrasted with the bottom-up approach which is more ideal for semantically-rich images where multiple objects within the image are first identified and then given to the encoder. (Anderson et al., 2017) Datasets that have high-quality and semantically-rich images, such as MSCOCO, are more ideal for the top-down approach.

During training, sequences are padded then ordered by length in order to minimise computations. Word embeddings, attention weights, and the decoder all have a dimension of 512 with a batch size of 32. The encoder’s learning rate was 0.0001 and the decoder’s learning rate was 0.0004. Early stopping was implemented after 20 epochs of no improvement in the model’s BLEU-4 score. These hyperparameters and implementations were all chosen through the tutorial source.

The greedy search algorithm was implemented for generating captions. In the greedy search algorithm, when given a number of choices for the next stage, the model will always choose the best immediate output. For this task, the language model takes the vocabulary’s logits and turns them into probabilities. This is then fed to the greedy search algorithm where it chooses the highest probable word to occur next at each stage. However, this algorithm also has its drawbacks. Since it only chooses the best immediate output and does not look farther ahead, it has a lower chance of reaching the globally optimum solution—hence its name, *greedy* search.

## 4 Results

Upon initial review, results were abysmal but with further examination and analysis, lessons were learned. In this section, results will be presented and their probable causes will also be explained. The sections following will include the extrapolations of the results and the conclusions that come with them.

The corpus-BLEU score was used as the main measure for this project which requires a list of references (the human-made annotations) and a candidate (the predicted caption). The score is the

average of the scores between the candidate and each reference. Both sentence-BLEU and corpus-BLEU calculate the cumulative 4-gram BLEU score (BLEU-4) by default. Although a great option to calculate scores for a task that has more than one caption, longer sentences also lead to lower scores. Since the variation of lengths, even with a minimum of 8 words per caption, are quite large, this task will still be affected as seen on Table 1. Detailed captions are also valued for this task. However, the detail provided by annotators are often distinctive to the individual as annotators were encouraged to summarise texts and decide what in the image they think might be important for a blind person.

	<b>Loss</b>	<b>Accuracy</b>	<b>BLEU-4</b>
<i>BC</i>	4.114	64.060	0.142178
<i>TEST</i>	4.181	63.941	0.145776

Table 1: Loss, Top-5 Accuracy, and BLEU-4 scores for the best performing model (BC for best checkpoint) during training and testing.

The training process also included a mechanism that saves and labels the best performing model as a checkpoint which will then be used for validation and testing. Figure 2 and Figure 3 show the loss and accuracy curves during training. The blue circle marker indicates the model used for validation and testing. In both curves, there are clearly other epochs where the model’s loss was lower, and the accuracy was higher. However, the model chosen to proceed with was decided through the highest BLEU-4 score. This can also be seen in Table 2 where the highest accuracy was attained on epoch 12 while the highest BLEU-4 score was attained on epoch 14.

The BLEU-4 score was incredibly low since the captions being generated by the model did not match any of the human-made captions. Since it is difficult to also trust such varied human-made captions as the gold-standard, a manual inspection of the generated captions was done. Below are some examples of what majority of the generated captions looked like:

“white background”

“a close up of a white background with a black background”

“a close up of a black background with

Epochs	Top-5 Accuracy	BLEU-4
0	55.982	0.1047
1	59.216	0.1180
2	60.894	0.1277
3	62.122	0.1307
4	62.798	0.1362
5	63.192	0.1371
6	63.632	0.1404
7	63.87	0.1429
8	64.06	0.1421
9	64.045	0.1440
10	64.1	0.1447
11	64.112	0.1449
12	<b>64.193</b>	0.1451
13	64.031	0.1445
14	<b>63.923</b>	<b>0.1465</b>
15	63.912	0.1461
16	63.808	0.1460
17	63.753	0.1459
18	63.526	0.1456
19	63.594	0.1452
20	63.283	0.1427
21	63.275	0.1429
22	62.96	0.1434
23	63.015	0.1421
24	62.811	0.1422
25	62.629	0.1419
26	62.436	0.1423
27	62.424	0.1416
28	62.383	0.1400
29	62.144	0.1383
30	62.031	0.1403
31	62.002	0.1382
32	61.882	0.1389
33	61.649	0.1370
34	61.53	0.1383

Table 2: Top-5 accuracy and BLEU-4 score after each epoch during training. The row highlighted in yellow is the model that performed the best and what was used for validation and testing.

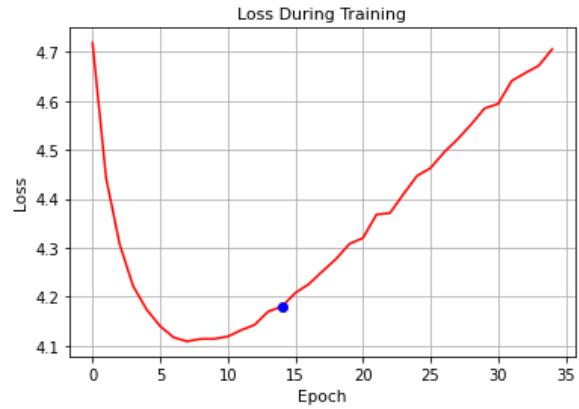


Figure 2: Loss curve during training. The blue point is the loss for the best performing model based on its BLEU-4 score.

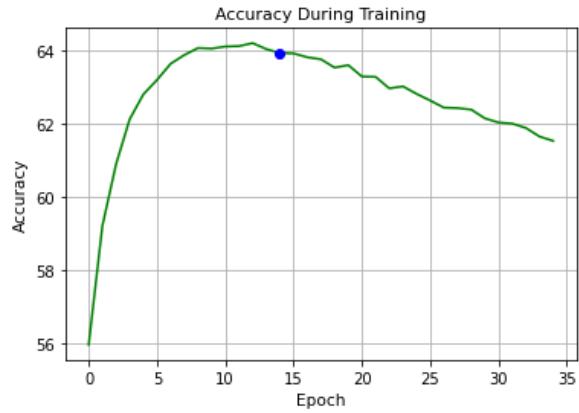


Figure 3: Accuracy curve during training. The blue point is the accuracy for the best performing model based on its BLEU-4 score.

a white background with a white background”

“a close up of a black background with black lettering”

“the photo is cropped out of the frame”

The captions seem to be recursive and only use words and phrases that refer to the image’s background, alternating from *black* and *white*. These captions are a result of the *greedy search algorithm* since a large amount of the human-made captions had these phrases at the end of the captions.

In evaluating the attention in [Figure 4](#), [Figure 5](#), [Figure 6](#), there seems to be a pattern in where the model is looking while generating captions. The model begins by looking at the entire image, then attends to the middle of the image, typically in the top right and makes its way to the bottom left.

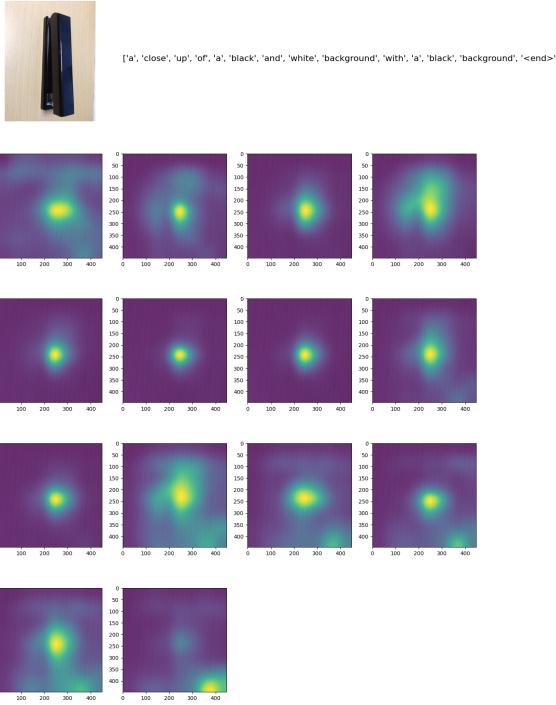


Figure 4: Attention visualized for captioning an image of a stapler in the wrong orientation (portrait instead of landscape)(VizWiz\_train\_00013366.png).

The purpose of visualizing attention is not being achieved and these visualizations do not connect nor ground the captions the model has generated for their respective images.



## 5 Discussion

Although Xu et al. (2015) presented a state-of-the-art model that performed incredibly well in generating captions for images, this same model being trained on a domain-specific dataset such as VizWiz was unsuccessful. Captions that are considered to be useful for this task does not only require identifying objects in an image. Additionally, acceptable captions can vary in length, style, and wording. There is a lot of space for a caption to be successful despite the specificity and detail it requires.

The language patterns learned by the model through the human-made captions also seemed to be not useful at all and could be argued to be detrimental. A post-hoc investigation of the human-made captions was done and many annotators seemed to follow a common template for what is deemed to be succinct and effective—begin with describing the foreground and any item that seems to be the focal point, mention any text that appears, describe the background. This kind of template is

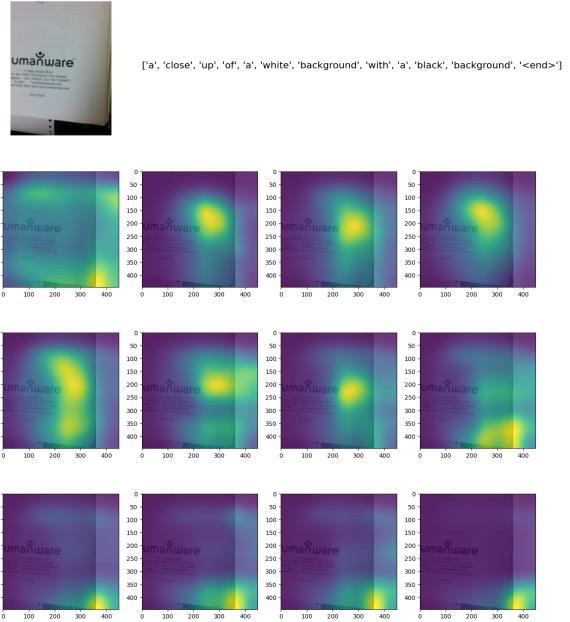


Figure 5: Attention visualized for captioning an image of a white page with text (VizWiz\_train\_00023423.png).

not ideal for generating captions for images as the words that will often come up in describing text or the background will always be chosen when used with the greedy search algorithm. Once a word with a very high frequency is chosen, the model will continue to choose the common phrase such as “on a white background”. This tendency will turn into a recursive caption like the example given in Section 4, “a close up of a black background with a white background with a white back-ground”.

There are also data limitations when it comes to the images being fed into the model. Since the photographs were taken and submitted by real-word users, people who are visually-impaired, it should be acknowledged that the images are not of the best quality. Images are described to “often contain text, exhibit a high variability in image quality, and contain a large diversity of content”. (Gurari et al., 2020) In majority of the images, the object in question is not framed properly and we only have a partial view of said object. Focus of the object or clarity is at times also absent in the images. The importance of interpreting and summarising text for this task also creates an obstacle for a typical image caption generator. There are many characteristics of a photograph that we take for granted when implementing models that generate captions. The difference in orientation of an image should also be taken into consideration. In Figure 4, a



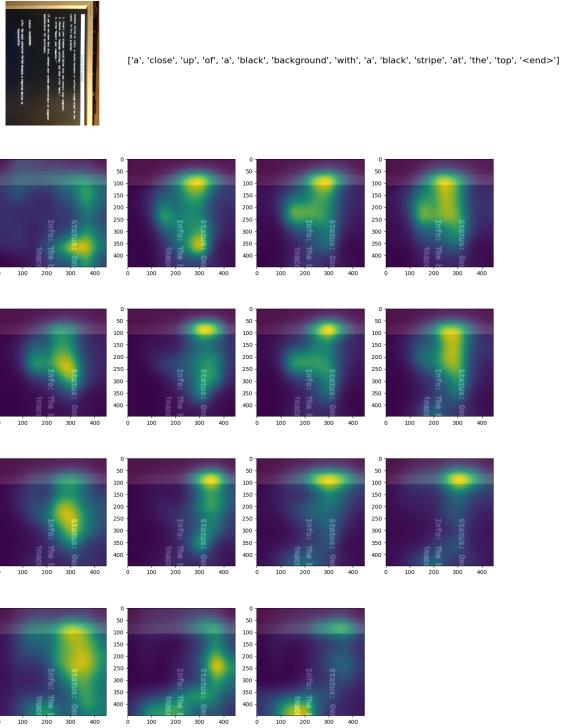


Figure 6: Attention visualized for captioning an image of a black screen with text in the wrong orientation (portrait instead of landscape)(VizWiz\_train\_00000858.png).

model might have a better chance in identifying the object as a stapler if the image was on landscape rather than portrait—the “prototypical” position of a stapler. It is crucial to recognise that images and captions (from datasets such as MSCOCO and Flickr8K) being used to train image caption generators are of high-quality and are quite idyllic compared to the images used to train the model for this project.

In terms of attention and seeing what the model is looking at while generating the captions, it is a good sign that the attention is quite general in the beginning. However, since the captions are not competent and do not refer to anything in the image, it is not possible to ground the text generated with the image and vice versa—creating a bigger semantic gap. With these results, the question of whether attention is even useful or needed for this task is brought up. Attention was initially added into translation models to account for long dependencies and this intuition is successfully applied for images with many objects. Since this task generally requires a caption that describes the focal point or one object, it might be the case that attention is not actually necessary. Another important consideration is the

difficulty of replicating human-made captions. As van Miltenburg (2019) states, human-generated image descriptions are rich and subjective. There is “virtually [an] infinite set of different ways to describe an image [and] people will use their own knowledge and expectations to choose from all of those options how an image should be described.” (van Miltenburg, 2019) With an infinite amount of options scattered amongst the captions provided, it is incredibly difficult for a model to learn effective patterns to describe an image like a human would.

## 6 Conclusion & Future Work

In this paper, a well-renowned and successful model architecture was implemented with a domain-specific task in mind. Using the VizWiz-Captions dataset to address a real-world application of automated image captioning, the model was incredibly unsuccessful in generating captions considered to be useful for the task at hand. Standard captioning with no pre-training other than the domain-specific task dataset gives a very low performance and training must be done outside of the task dataset and then finetuned. The shortcomings of the greedy search algorithm and overlooked limitations of the dataset also contributed to the poor performance of the model. It is extremely crucial to be critical of the data and how it could influence training—both in improvement and detriment. van Miltenburg (2019) states “image description literature has generally avoided these issues by delegating them to the crowd-workers annotating the images.” It is important for both the computer vision and natural language processing communities to consider finding ways to further improve already state-of-the-art models for domain-specific tasks as these would have real-world effects on a very large demographic. The architecture can also be questioned as being too simple... or not? There are many more mechanisms that must be implemented in order to account for the components that make this specific task very difficult. However, it could also be said that since the images are much more simpler than typical image captioning photographs, the model should be simpler but given more information.

### 6.1 Future Work

#### 6.1.1 Model Architecture

Alterations to the model architecture would include choosing the beam search algorithm over greedy

search since it seems to have caused one of the bigger, more tangible bottlenecks. The beam search algorithm would be more likely to choose the globally optimum solution and deliver more sophisticated and specific captions. The ability to choose the beam size would also allow more flexibility in how far ahead the model should look when making choices at each timestep. Another alteration to consider would be implementing a visual sentinel as Lu et al. (2016) have proposed. The model would then have the ability to decide whether to rely on the language model or the image through the sentinel gate. This option could give more accurate captions since there will be the chance to prioritise visual information over the word most likely to occur beside the previously chosen word. Evaluating the generated captions using more than one evaluation score would also be more informative. Using metrics such as CIDEr and METEOR would be beneficial to analyse the generated captions.



### 6.1.2 Task-Specific Improvements

After examining the data further after already having implemented the model and considering the symbiotic relationship between the dataset and model architecture, some task-specific additions might improve the model's performance. Since there seemed to be a common-template for what is considered to be an effective caption, implementing some sort of rule-based template for the captions first and foremost might help with creating a more realistic and useful caption for the target demographic. Another important consideration is



the vital need to read and summarise text in images. Implementing some form of optical character recognition (OCR) and text summarisation would be extremely helpful. A mechanism where if text is detected, it will be used. Additionally, since annotators were instructed to summarise the text rather than repeating what is said, summarising the text output of an OCR mechanism could possibly better mirror the human-made captions in the dataset.



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