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Generalized Abstractive Text Summarization Using Optimized Transformers

Literature Review

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**Acronyms**

|  |  |
| --- | --- |
| AI | Artificial Intelligence. |
| DL | Deep Learning |
| GUI | Graphical User Interface |
| ML | Machine Learning |
| NLP | Natural Language Processing |
| ROUGE | Recall-Oriented Understudy for Gisting Evaluation. |
| BLEU | BiLingual Evaluation Understudy. |
| T5 | Text to Transfer Transformer. |
| BART | Bidirectional Auto-Regressive Transformers. |
| BERT | Bidirectional Encoder Representations from Transformers. |
| PEGASUS | Pre-training with Extracted Gap-sentences for Abstractive Summarization Sequence-to-sequence |
| ILP | Inductive logic programming. |
| LSTM | Long Short-Term Memory. |
| RNN | Recurrent Neural Network. |
| CNN  SEQ2SEQ | Convolutional Neural Network.  Sequence to Sequence |
| RoBERTa | Robustly Optimized BERT Pre-training Approach |
| GPT-3  REST  GPU | Third Generation Generative Pre-Trained Transformer  Representational State Transfer  Graphical Processing Unit |

# CHAPTER OVERVIEW

In this chapter, the author presents critiques on prior relevant work about the use of abstractive text summarization in the domain of movie review summarization, along with the usage of advanced deep learning approaches such as transformers. Additionally, the author tries to create a generalized model that will handle several other domains in addition, not just to only the movie domain.

Finally, the author determines the optimal transformer design that has been improved in order to produce the greatest outcomes by obtaining the optimum set of hyperparameters by model fine-tuning, performing hybridization and adaptive model retraining with new data and hyperparameters.

# CONCEPT MAP

The concept map illustrates the project scope that will be addressed in this literature review, and the nodes that are highlighted correspond to the project's primary study areas. The concept map was created to ensure that all necessary literature was covered. The concept map can be found in [**Appendix A – Concept Map**](#ConceptMap)**.**

# PROBLEM DOMAIN

The simplicity of selling products or services to customers is growing along with the usage of technology and the internet. Sellers utilize customer feedback to better decide how to improve sales and so attain customer satisfaction (Boorugu, Ramesh and Madhavi, 2019). When it comes to movies, people typically find it quite challenging to quickly determine whether a movie meets their demands by reading the reviews, which may occasionally be very lengthy and time-consuming (Khan et al., 2020).

## **User Reviews**

A user/customer review is typically referred to be written feedback from a customer who has used a product or service. Consumers frequently use user ratings and reviews to drive their purchasing decisions. Because the review data is unstructured, it becomes more challenging for consumers to compare and understand lengthier reviews (Lackermair, Kailer and Kanmaz, 2013).

User and customer reviews are extremely important to major corporations like tourism and hospitality as they constitute the primary engine for the country's economic growth and development. where tourists from over the world may blog about their experiences and share their reviews online in numerous formats (Mukherjee et al., 2020).

## **Corporate Advantage**

It is also known that it costs at least five times as much time and money to acquire a new customer as it does to keep an existing one, so it is important to learn how to foster customer loyalty to the brand, business, or service that is being offered. Customer satisfaction is essential to the survival of corporate industries. Understanding client expectations through their feedback or reviews helps business industries grow and fix faults (Pizam and Ellis, 1999).

On the other hand, companies like Netflix or Amazon Prime can use the movie summaries to help users and understand the watching pattern or their interest. Likewise, the movie-related industries need to allow the customers to quickly scan the summary and quickly decide whether they should be watching it or not (Khan et al., 2020).

## **Text Summarization**

With the massive accumulation of information/data on the internet nowadays, it is extremely difficult to extract relevant information from a large number of textual documents. The goal of text summarizing is to provide a condensed yet meaningful version of a lengthy textual content (Shi et al., 2020).

We all know that text summarization has several uses in a variety of internet-based fields, including search engines that are used for querying and e-commerce sites that utilize sentiment analysis to determine client satisfaction with items (Etemad, Abidi and Chhabra, 2021).

However, in the movie industry, consumers may utilize text summarization to simplify customer reviews of movies, which are often lengthy and time-consuming to read. This enables users to make better decisions when they decide whether or not to watch a certain movie (Khan et al., 2020).

## **3.4 Abstractive and Extractive Techniques**

Generally, text summarization is classified into two which are; abstractive text summarization and extractive text summarization, however the approach for creating a hybrid model for text summarization is possible (Alsaqer and Sasi, 2017). The abstractive text summarization technique aims to produce the sentences on its own and then uses them to provide a coherent summary. Therefore, the summary's content will vary from the original context yet still convey the same idea (Mahajan et al., 2021). Additionally, it is well recognized that a strong abstractive summary encompasses the input's key details and is linguistically fluent (Zhang et al., 2020).

The extractive text summarizing method focuses on picking out key phrases or groups of phrases from the original input content and combining them to produce a concise yet insightful text summary. It is determined which sentences should be included as parts of the summary based on the statistical and linguistic characteristics of the sentences (Gupta and Lehal, 2010). A hybrid system is one that combines various strategies to produce a single system. However, hybrid text summarizing systems do exist, for instance, using a combination of extractive and abstractive summarization can be utilized to generate a hybrid system that uses encoder-decoders (Kirmani et al., 2019; Abolghasemi, Dadkhah and Tohidi, 2022).

*Table 1: Comparison of Text Summarization Techniques*

|  |  |
| --- | --- |
| **Abstractive** | **Extractive** |
| Paraphrases content like humans do, meaning it creates its own context (Mahajan et al., 2021) | Doesn’t create its own context but uses the best possible phrases from the original document (Gupta and Lehal, 2010) |
| A vast number of datasets are available to experiment working in this domain. | Capable of visualizing sentence scores and investigating gradient-based ways to calculating the contribution of each input token to score prediction (Pai, 2014) |
| There is a probability of creating information which may be faulty or that gives a different in meaning compared to the original text. | There is a possibility that the combined sentences made from the extracted sentences will contain errors. |

## **3.5 NLP with Deep Learning**

NLP is a method for computers to intelligently and effectively analyze, comprehend, and derive meaning from human language, as opposed to other approaches that only focus on the interactions between human language and computers. Deep learning techniques are increasingly being used in the field of AI compared to traditional machine learning approaches due to their success rates in handling difficult high computing learning tasks (Lopez and Kalita, 2017; Mahajan et al., 2021).

In today's NLP, machine learning is prominent, but for the most part it only involves numerically optimizing the weights of characteristics and representations that have been created by humans. Deep learning aims to investigate how computers can utilize data to create features and representations suitable for challenging interpretation tasks (Socher, Bengio and Manning, 2012).

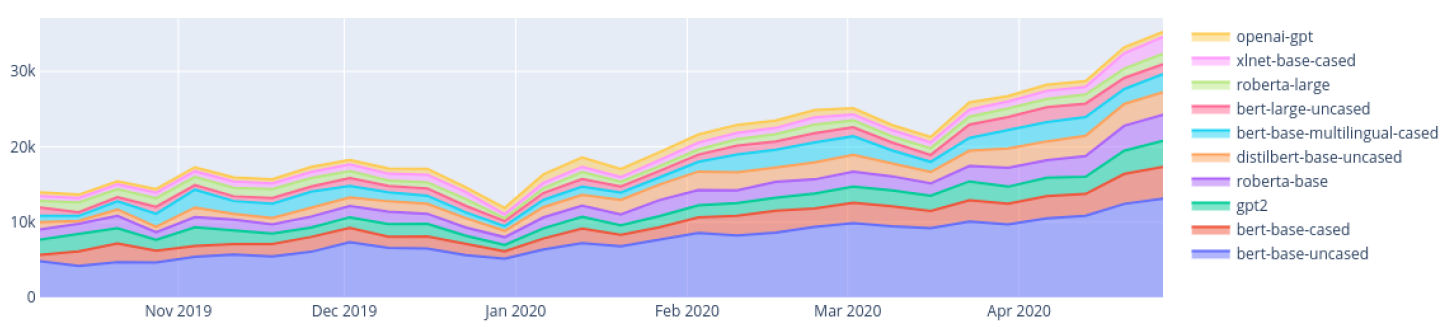
## **3.6 Transformers**

Open-source library Transformers contains modern transformer architectures that have been thoroughly developed and are integrated by a common API. Pretraining has enabled the efficient use of this capacity for a wide range of activities, and these designs have permitted the construction of higher-capacity models. Transformers are designed to be easy for practitioners, expandable for researchers, and quick and reliable in industrial deployments (Wolf et al., 2020).

It has been demonstrated that the modern generation of pre-trained language models based on transformers is rather competent at identifying syntactic signals like noun modifiers, possessive pronouns, prepositions, or co-referents, as well as semantic cues like entities and relations (Brasoveanu and Andonie, 2020).

Hugging Face Hub offers a variety of transformer designs, including BERT, GPT2, T5, PEGASUS, and many others. The figure below represents the daily average for unique downloads of the pretrained transformer model architectures between Oct 2019 to May 2020 (Wolf et al., 2020).

*Figure 3.1 – Transformer Architecture Downloads Rate (Wolf et al., 2020).*



(Etemad, Abidi and Chhabra, 2021) research compares various other researchers approaches taken in order to perform abstractive text summarization, these techniques includes the use of transformers and other neural network approaches such as CNN and LSTM RNN networks. The research comparison table below only includes the approaches of transformers used taken abstractive text summarization.

## **3.7 Hyperparameter Tuning**

Finding the ideal collection of parameter values to train an algorithm using in order to build a model relevant to the dataset is known as hyperparameter tuning (Liu and Wang, 2021). The calculation of the performance improvement that may be obtained by changing the value of each of the considered hyperparameters from the original value to the value indicated in the target configuration set by the tuning strategy is where hyperparameters make the biggest contribution to improving algorithm performance (Joy and Selvan, 2022).

There are several hyperparameters that play a significant role in performance enhancement; however, not all of the parameters do so; just a select handful do, for example, learning rate, weight decay, number of epochs, batch size, and warmup ratio. As a result, giving critical hyperparameters a higher priority is crucial (aws.amazon.com, 2022).

Automated framework tools, such as Optuna, an open-source framework for hyperparameter optimization built on the Python programming language, does hyperparameter tweaking. The application of numerous hyperparameter optimization techniques, including Grid Search, Random Search, TPE, and CMA-ES algorithms, was made easier by this framework (Joy and Selvan, 2022).

## **3.8 Generalization**

Generalization now plays a significant part in resolving issues in numerous fields that are linked to the same issue. The capacity of a model to generalize to new, previously unobserved data that comes from the same distribution as the model's original data is known as generalization (Neyshabur et al., 2017).

Generalization is a useful strategy for starting with the foundation and improving or specializing in one's field as more unseen domain data becomes available. Therefore, the generalized solution will be able to adapt to even unseen domain data, making this solution to solve a common problem in multiple domain (Zhou et al., 2021).

## **3.9 Data Expansion**

The quality of a machine learning or deep learning model depends on a number of factors, one of which is the amount and quality of data fed during model training. There are several approaches to increase or expand your available data one of which is data augmentation (making use of existing data points to create new data points). Making using of new data from the users end by saving as the model is used is another way of exposing new data for model retraining (Shorten and Khoshgoftaar, 2019).

When generalized models are required to adapt to become domain specific, model retraining will be considered with new data used by the specialized domain as the application is used.

# EXISTING WORK

There have been several works done on abstractive text summarization for the field of movie reviews, mainly using the traditional machine learning algorithms. However, there are several limitations which created the need for recent deep learning approaches in order to improve the **system’s performance.**

## **4.1 Text Summarization Systems.**

There were multiple studies done previously in the area of text summarization, regarding both abstractive and extractive text summarization. (Khan et al., 2020) research is related to the domain of movie reviews summarization which is the same as this project domain, where the author has developed an automatic approach to summarize lengthy movie reviews along with the feature where the users are allowed to quickly recognize the positive and negative aspects of the movie with respect to the review processed with. The text summarization approach taken by the author is **extractive approach**, where sentence score ranking plays a major role in creating the summary.

The study of (Boorugu, Ramesh and Madhavi, 2019) is towards the domain of ecommerce but yet related to text summarization for customer reviews on the products they sell, so purpose being that, allowing other customer make better purchasing decisions on products, therefore the hassle of going through all the reviews to making a purchasing decision can be reduced to save time, **abstractive approach** is considered to create the summary, which is a better choice of approach.

The research of (Mukherjee et al., 2020) is another **extractive approach** for text summarization where the author develops a solution for generating personalized aspect-based opinion summaries using a dataset which consists of a large collection of online tourist reviews. In addition, the author has gone a step further to personalize the summary's qualities by using the user's interest. However, using abstractive summarization would be a more effective strategy but also challenging when user interest customization is considered because the sentences have been created using own words rather than with any sentence ranking technique.

(Gupta et al., 2021) research is a comprehensive comparison study with benchmarking results of various pretrained transformer architectures such as BART, BERT, T5, PEGASUS etc... for abstractive text summarization which is an **abstractive approach.** This study includes the various types of datasets been used to explore each model with they evaluations as benchmarking results. The author has also concluded the best performing transformer architecture as **T5** by comparing the evaluation results of the study.

The study conducted by (Mahajan et al., 2021) is also an **abstractive approach** to text summarization with the addition of proper grammar and no repeated words used using a deep learning approach with RNN and likewise (Etemad, Abidi and Chhabra, 2021)research also relates to an experimenting study with various deep learning approaches for abstractive text summarization along with the evaluation benchmarking with a goal in search for the best deep learning approach for the problem.

## **4.2 Algorithmic approaches for Text Summarization**

As described in this literature review's Problem Domain section, deep learning approaches are mostly given priority to than traditional machine learning approaches as they can handle highly computational tasks. The author came across of multiple deep learning techniques used aswell as machine learning techniques used for handling abstractive text summarization.

The study of (Khan et al., 2020) starts by first focusing on feature extraction, then transforming reviews into vector spaces, and applying the Naive Bayes machine learning method for review classification utilizing an undirected weighted graph-based ranking algorithm to rank score for each review phrase in graph and then, in order to construct the extractive summary, the highest scoring sentences are selected. However, the author has limited the use of sophisticated deep learning algorithms to improve performance by solely using standard machine learning approaches to tackle the problem.

(Boorugu, Ramesh and Madhavi, 2019) research made use of seq2seq model for text summarization along with the attention mechanism for improved accuracy and the Concept net Number batch word embedding model, which is superior than Glove. Utilizing a 1D convolutional layer, a max pooling layer, an LSTM layer, and finally a fully connected layer at the very end. However, the author's use of generic deep learning algorithms to handle this problem introduces a new constraint that prevents performance from being improved using the most recent deep learning strategy for NLP-related problems, transformers.

The research of (Mukherjee et al., 2020) liked mentioned earlier is an extractive method text summarization based on integer linear programming (**ILP** [Unsupervised method]) to choose an informative subset of opinions centered on the identified aspects. Utilize ROUGE-based criteria to assess and contrast the summaries and get competitive outcomes. Since the dataset is also constrained, extractive summaries could not be particularly insightful; thus, utilizing an abstractive technique might produce superior results, despite the dataset's constrained size.

The study of (Mahajan et al., 2021) focus of the authors' study is utilizing the **encoder-decoder** model with the attention layer to produce text summaries with good syntax and no repeated words. the creation of an encoder-decoder model with gated recurrent units and training it to provide an abstract summary of a piece of writing. Although the author employed deep learning, its application in production required real-time training so that it could be updated with the most recent content over time.

## **4.3 Usage of Transformers**

(Gupta et al., 2021) research employed pretrained models such Pipeline BART, BART modified, T5, and PEGASUS to deal with text summarization as a part of the comparison study done. The ROUGE Scores were used as the evaluation measures. During the experiments, the author employed transformer designs; however, the **hyperparameters** used were **default** and might be tuned for a better performance. The constraints consist of concentrating on developing more reliable models that can further expand the method to produce summaries of varying length and applicable for multi-document summarization.

(Etemad, Abidi and Chhabra, 2021)The author explores with deep learning methods in the broad text summarization domain to determine which method—among a collection that includes RNN, CNN, and Transformers—performs best. The author also considers metrics for model evaluations including BLEU and ROUGE, despite using sophisticated deep learning algorithms, the author was unable to undertake **hyperparameter** tuning to improve the method and obtain a better outcome.

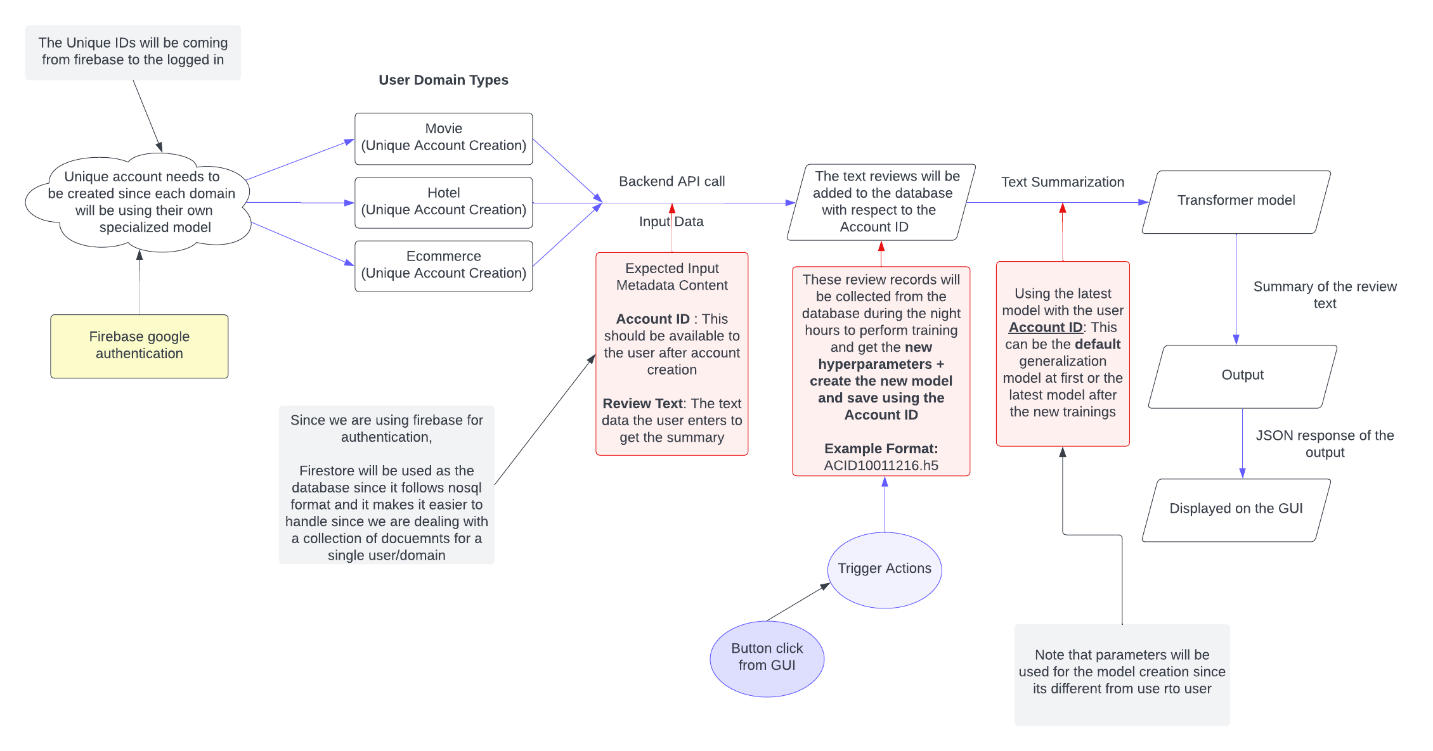
# TECHNOLOGICAL REVIEW

There are many applications for text summarization systems today, especially when researching papers. Users may choose from a variety of contexts, such as research paper materials, customer reviews, etc., much more easily by using summaries to comprehend the context and pinpoint the key concepts. Text summarization tools assist researchers in frequently writing an abstract of their findings. With this technique, text summaries may be extracted or abstracted. In contrast to extractive text summarizing, the abstractive text summarization approach creates its own context, which is a far more logical or human-like written language, and can help with problem solving (Barna and Heickal, 2022). Text summarizers may be quite helpful in highlighting the key elements of reviews by providing a summary of user reviews, which can sometimes be very extensive and descriptive.

Traditional machine learning and deep learning approaches has been widely used for text summarization for the domain of movies reviews, however advanced deep learning approaches such as Transformers has not been explored for the domain of movie reviews but yet been used in other case scenarios. Even though traditional machine learning and deep learning approaches performed well, there was a limitation to push the boundaries with new approaches. That’s where transformer optimized was considered via repeated hyperparameter tuning with exposure to new data and making this generalized to any domain.

## **Proposed architecture for the Generalized Text Summarization System.**

Figure 3.2 – Proposed Generalized Abstractive Summarization System Process Flow



## **5.2 Machine Learning text summarization techniques.**

(Boorugu, Ramesh and Madhavi, 2019) points out a previous research where a system was built that uses a hybrid classifier approach with machine learning algorithm combination of SVM and Naïve Bayes in sync with fuzzy logic and they also concluded that with the increase in the classifier count the accuracy can also be increased. They also made use of supervised ML algorithms such as KNN for the classification of the reviews which then combining appropriate words for identifying the features of the product.

(Khan et al., 2020) proposed system was for the movies domain using the customer reviews, the author broke down proposed methodology into segments of which is preprocessing, feature extraction, review classification and finally review summarization. The Nave Bayes (NB) classification method, which is regarded as a robust classifier and may achieve greater accuracy, was used to categorize the reviews from negative to positive using supervised ML classification technique, It is clear that an extractive summarization approach was used because the text summarization phase was completed in several stages, starting with the creation of a graph from classified reviews, followed by the ranking of graph nodes and the selection of the top rank sentences for the summary generation.

Initially, these machine learning methodologies were given a lot of significance, but as time has progressed on, new technologies and techniques have emerged that can utilize deep learning techniques like RNN, CNN, etc. to perform better.

## **5.3 Deep Learning text summarization techniques.**

Numerous studies have been conducted on deep learning methods for abstractive text summarization, such as with the usage of CNN, LSTM-CNN, Convolutional Seq2Seq, Sequence to Sequence RNN, Convolutional Sequence to Sequence, Transformers, T5, BART, BERT etc.… which were trained on a general dataset such as from Gigaword, DUC 2002, DUC 2004, CNN Daily Mail, DUC, Xsum, Newsroom such datasets, in order to get an evaluation comparison on which outperforms the rest and eventually the T5 Transformer outperformed the rest of the other techniques in the case of abstractive text summarization (Etemad, Abidi and Chhabra, 2021).

(Shi et al., 2020) has conducted a thorough analysis of latest developments in seq2seq models for the task of abstractive text summarizing. The author's analysis includes a full review of several distinct seq2seq models for abstractive summarization.

Out of which transformers are the advanced deep learning approach for text summarization which is an encoder-decoder model with attention layer which helps it to generate better results than a traditional simple RNN architecture (Mahajan et al., 2021).

## **5.4 Available Datasets for generalized text summarization.**

There are two datasets that the author will be exploring throughout the development of this project. One of which is the Amazon movie reviews dataset from Stanford University Education, which contains data within the span period of more than 10 years including 8 million review data records (McAuley and Leskovec, 2013).

This dataset will be used to test out the solution for the problem domain which is abstractive text summarization for movies. Given that the author is able to create the solution for the domain of movies then, the author then plans to generalize the solution using another dataset named as Gigaword which is from TensorFlow datasets which was used previously for creating generalized content for text summarization (Kouris, Alexandridis and Stafylopatis, 2019).

## **5.5 Preprocessing techniques used in text summarization.**

Text preprocessing is very important when it comes to dealing with text related data. In earlier studies, a variety of text preprocessing approaches were utilized for text summarization.

Sentence segmentation is a fundamental step in NLP applications including IR, machine translation, semantic role labeling, and summarization. It is the process of identifying boundaries within a document that divides the document's text into sentences, typically from a strong point of punctuation like (full stop, explanation mark, question mark, etc.), Tokenization and stop words removal will then be performed. Tokenization will be carried out by the tokenizer program to split the sentences into distinct words by splitting them at whitespaces such as blanks, tabs, and any strong punctuation. Stop word removal is also used to remove frequently used words in the document such as "I," "an," and "a" because these words carry little meaning and are best removed from the document (Khan et al., 2020).

Other researchers have incorporated a variety of other techniques, including noise removal, which eliminates unnecessary text from the input document, such as the header and footer, and named entity recognition (NER), which recognizes words in the input text as names of things like people, places, and things, among others (Barna and Heickal, 2022).

Datasets may also contain unwanted records, null records, or redundant records that are absolutely useless. These records or rows with null values are eliminated, unnecessary HTML tags and URL links are also filtered off from the text as a part of text preprocessing. Contraction mapping is crucial and this will be handling which are converting short word formats into longer such as “aren’t” into “are not”. Converting the entire text content into a single case most preferably to lowercase, therefore further character filtration would become very simpler (Mahajan et al., 2021).

# EVALUATION TECHNIQUES

## **Evaluation Approaches**

A machine learning model's performance, as well as its advantages and disadvantages, are understood through the process of model evaluation, which employs many evaluation measures. During the early stages of research, it's critical to evaluate models to determine their efficiency.

The table below shows the available measure and the metrics that can been used to **quantitatively** evaluate the text summarization system.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure** | **Description** | | **Objective Orientation** |
| **Metric: 01** | | | |
| ROUGE | ROUGE also known as Recall-Oriented Understudy for Gisting Evaluation. Measures are made by comparison between an automatically generated summary/translation against a group of reference summaries (generally human created summaries) (Lin, 2004). ROUGE measures the **recall,** (according to how frequently the terms from the summaries created by humans appeared in those computer - generated.) | | Positively oriented.  Higher, the better |
| **Equations** | | | |
| **Rouge-1** | | | |
| Refers to the system summary and reference summary's overlap of unigrams (one-word sequence)*.* | | | |
| **Rouge-2** | | | |
| Refers to the bigram (two-word-sequence) overlap between the system and the reference summaries | | | |
| **Rouge-L** | | | |
| Measures the longest matching word sequence | | | |
| **Metric: 02** | | | |
| BLEU | | BLEU also known as Bilingual Evaluation Understudy is a metric used for evaluation for the quality of machine generated text by comparing it with a reference text that is supposed to be generated. (Steinberger and Jezek, 2009). BLEU measures the precision (as to how much words in the generated summaries appeared in the human generated summaries) | Positively oriented.  Higher, the better |
| **Equations** | | | |
|  | | | |

Different versions of ROUGE exist, including ROUGE-1, ROUGE-N, ROUGE-L, and ROUGE-S. For example, ROUGE-L considers the longest common sequence, whereas ROUGE-S and ROUGE-SU consider skip sequences. (Etemad, Abidi and Chhabra, 2021). Out of which ROUGE-1, ROUGE-2 and ROUGE-L is considered as the least number ways to get a proper evaluation of the model and the scores lies between 0 to 1. Higher the score, the better.

(Steinberger and Jezek, 2009) Out of both of these evaluation metrics ROUGE score demonstrates the best performance for text summarization as compared to BLEU. (Lin, 2004)claims that they introduced ROUGE, an evaluation package for summarization, and carried out thorough evaluations of the automated measures present in the ROUGE package using three years' worth of DUC data.

## **Benchmarking**

The table given below is the benchmarking results of training transformers with generalized datasets for abstractive text summarization. The author will be also following the same measures for the evaluation benchmarking for the prototype, so it can be comparable.

*Table 3.1 – Comparison table for abstractive text summarization using transformers (Etemad, Abidi and Chhabra, 2021).*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Researcher | Year | Type of model | Rouge 1 | Rouge 2 | Rouge L | Dataset |
| Haoyu Zhang et al. | 2019 | Transformer with BERT | 41.71 | 19.49 | 38.79 | CNN-Daily Mail |
| Andrew Hoang et al | 2019 | Transformer | 39.01  36.73  40.87 | 17.87  14.93  28.59 | 36.17  29.66  37.62 | CNN Daily Mail  Xsum  Newsroom |
| Kaiqiang Song et al. | 2019 | Transformer | 40.89  45.93 | 19.11  24.14 | 37.60  42.51 | Gigaword,  Newsroom |
| Mike Lewis et al. | 2019 | BART | 44.16  45.14 | 21.28  22.27 | 40.90  37.25 | CNN Daily Mail  Xsum |
| Itsumi Saito et al. | 2020 | RoBERTa Base | 45.80  45.42 | 22.53  22.13 | 42.48  36.92 | CNN Daily Mail  Xsum |
| Beliz Gunel et al. | 2020 | Transformer XL | 34.273 | 13.018 | 32.048 | CNN Daily Mail |
| Colin Raffel et al. | - | T5 | 43*.*52 | 21*.*55 | 40*.*69 | CNN Daily Mail |

# CHAPTER SUMMARY

The problem, technology domains, prior work, and assessment strategies were all broken down in a concept map at the beginning of this chapter. Then, these four areas were further divided into subtopics and examined based on the research and ideas presented in earlier works of literature. A critical analysis of all the literature has been conducted, contrasting the likes and dislikes of earlier research, potential future work described in the literature, and unique approaches that the author of this study proposes as potentials not before explored.

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# APPENDIX A – CONCEPT MAP

