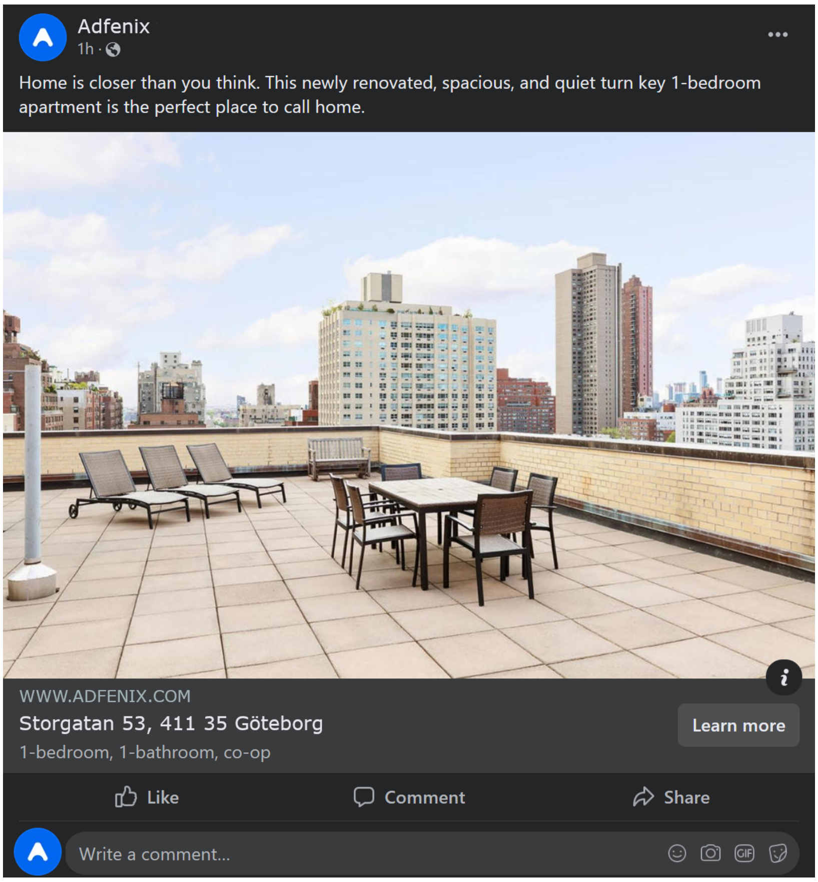

Novel ad text generation for real estate

Using reinforced transformer neural networks

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DEPARTMENT OF MATHEMATICAL SCIENCES
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022
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Master's thesis 2022

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Cover: Example of a real estate advertisement on the Facebook platform.

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Abstract

Transformer architectures have brought unreasonable progress to natural language generation in recent years. However, generating high quality and relevant advertising text is difficult. Inspired by Laban et. al., reinforcement learning is used in this paper to encourage a generative pretrained transformer to generate text that adheres to the norms and criteria of real estate advertising on social media. Using a proprietary dataset of real estate listings and ad copies, it is found that the architecture proposed by Laban et. al. is sufficiently modular and customizable for use in other domains, albeit with a modification to the pretraining procedure. Evidence is presented that the model's ability to embed desired information into the summary is contingent on the information being uncommon or unique.

Keywords: generative, pretrained, transformer, bidirectional, autoencoder, encoder, decoder, reinforcement, learning, natural, language, processing, generation, real, estate, online, social, media, ad, advertisement, copy, text

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Colton Cunov, Gothenburg, May 2022

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

GPT	Generative Pre-trained Transformer
BERT	Bidirectional Encoder Representations from Transformers
KPI	Key Performance Indicator
CTR	Click Through Rate
LEDE-n	The first n-sentences of a document
TF-IDF	Term-frequency inverse document-frequency

Glossary

Below are definitions of the vocabulary, parameters, and variables that have been used throughout this thesis.

Vocabulary

(ad) copy	The text present in an online advertisement
listing description	The plain-text part of a real estate listing, taken from a realtor's webpage
click-bait	Online content that misleads the viewer in order to drive traffic
impressions	The number of times an ad was seen by a viewer
click-through-rate	The ratio of the number of clicks to impressions an ad received
word (sentence) embedding	A numerical, often vector, representation of a word (sentence)
stop word	An unimpactful word (e.g. *the*, *and*, *it*) that is disregarded

Parameters

α	Importance weighting for the fluency score
β	Importance weighting for the coverage score
γ_i	Importance weighting for penalty i
ρ	Importance weighting for the modified summary score

Variables

$\vec{w}$	A summary or ad copy
$\vec{D}$	A document or listing description

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1
Introduction

With the rise of online advertising, real estate agencies have increasingly sought services to enhance quality lead generation from home buyers and sellers alike. Adfenix, a real estate marketing platform, equips agencies with services that drive engagement through effective advertising campaigns. These automated services include ad campaigns, where a parser extracts text from the real estate listing for use as social media ad copy.

Though simple to implement and computationally cheap, parsing social media ad copy from a real estate listing inherits certain drawbacks. The resulting text requires manual inspection to ensure grammar and spelling. It must also account for conventions on each agency's website, such as Covid warnings and showing details that may precede the desired text, and so must be unique for each customer.

Notably, this approach results in only one copy per listing. A/B tests are the cornerstone of advertising optimization, and with only one copy this is not possible.

The overarching goals of a real estate listing and an online advertisement are aligned: to drive engagement. However, there are differences. A real estate listing itself is an advertisement, whose goal is usually to provoke the viewer to e.g. enter their contact information or sign up for a viewing. Meanwhile, the goal of an online advertisement is to provoke the viewer to click. In current operations, the parser is designed to extract the first meaningful sentence from the listing, up until a character limit imposed by the social media platform. This sentence is usually enticing in some way, as it was likely written to provoke the viewer to continue reading and eventually, in conjunction with the rest of the listing, engage. However social media ads are usually limited to a few hundred characters and without the rest of the listing's support, this sentence may not be the most effective when used as ad copy.

1.1 Problem statement

This paper aims to generate novel social media ad copy for real estate property listings. With collaboration from social media advertising subject matter experts, an effective advertisement text is defined as:

"A short, fluent text that boosts the relevant selling points of a property"

In this definition, fluency pertains to readability (grammar, punctuation, diction, etc.). High fluency means the text "reads" as desired. Advertisements should also be relevant to the product or service they are offering and structured to boost (provoke) engagement, but not so overtly to be perceived as *click-bait*. Additionally, a character limit is imposed by the advertising platform.

Motivated by the lack of non-extracted ad copies, or summaries, in the dataset, the above qualities are encouraged to be included in the outputs of a generative pre-trained transformer (GPT) model using a modified version of P. Laban's The Summary Loop [2].

2
Theory

Unreasonable progress has been made in natural language processing due to neural networks in recent years. Higher quality datasets as well as hardware and support software (e.g. `PyTorch` and `TensorFlow`) improvements have equipped researchers with the necessary prerequisites to design and prove novel architectures.

2.1 Representing text as numbers

Text is often separated, or tokenized, into words or word-pieces in natural language processing. From these tokens, a word embedding[1] is a numerical representation, often a vector, that encodes the information of a word such that words with similar meaning are closer (as measured by e.g. cosine similarity) than those far away semantically. These can be static, where every word is mapped to a unique vector, or contextual, where the embedding for a word depends on itself and the surrounding words. The methods in this paper focus on the latter.

The static variety tend to be constructed with inspiration from distributional semantics, where terms are semantically categorized based on how they are distributed in large datasets. An acclaimed example is Word2Vec [14], which operates under a (continuous) bag-of-words or skip-gram procedure. In the bag-of-words approach, the input and target are a word and the words surrounding it, respectively, and vice versa for skip-gram. With both approaches resulting in similar performance, Word2Vec is a neural network with a single hidden layer employing one-hot encodings (see footnote) to generate trained, fixed-length vector representations of words with embedded meaning[2].

2.2 Foundational architectures in NLP

This section describes useful, antecedent architectures that influenced the design of, and whose foundations may be useful in understanding, those used in this thesis.

[1] Word embeddings can also be one-hot encodings, i.e. an all-zero vector save for one element where the length of the vector is the number of words in the vocabulary.

[2] e.g. "King" - "Man" + "Woman" = "Queen"

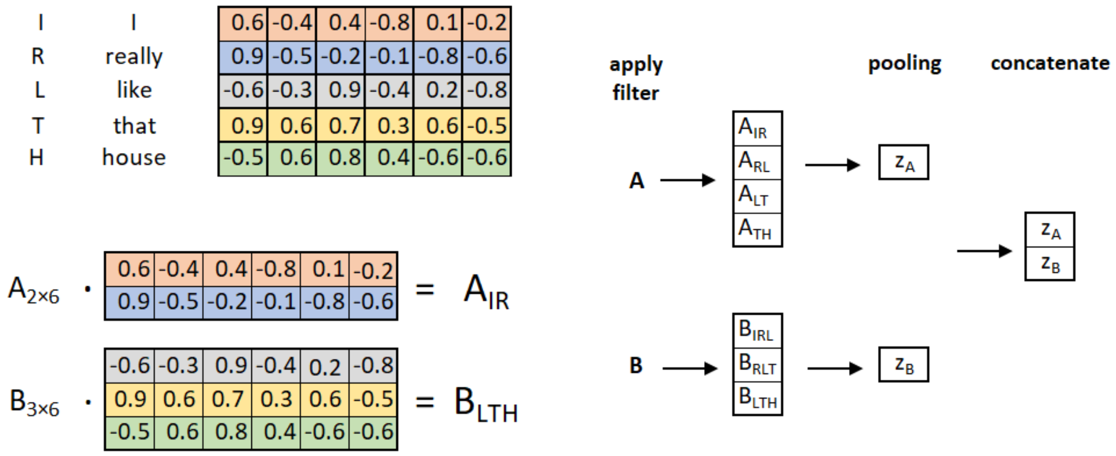


Figure 2.1: Convolution operations applied to a sequence (sentence) of word embeddings. A and B are filters of size 2 and 3, respectively.

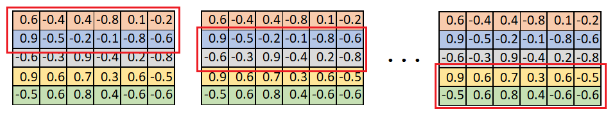


Figure 2.2: Illustration of the sliding filter of size 2. The dot products of each red region and A are concatenated to form the vector $[A_{IR}, ..., A_{TH}]^T$.

2.2.1 Fully-connected and feed-forward neural networks

Feed-forward neural networks are networks which propagate information in only one direction, forward. In fully-connected networks every node in layer i has an information pathway to every node in layer $i + 1$.

2.2.2 Convolutional neural networks

> [3]**Convolution** [kon-v*uh*-**loo**-sh*uh*n] *(noun)*
> *a rolling or coiling together*

Fixed-length vector representations of words can be stacked to form a sentence representation in matrix form[4]. Noting the similarity of this matrix representation to images, convolutional neural networks have proven useful in classification tasks such as sentiment classification and spam detection. They are able to extract features of the sentence at various scales from it's word-level components, from two-word (bigram) features to those that emerge at the multi-sentence level. It should be noted that due to the combinatorial nature of convolutions, they are generally not suitable for exposing features at the word-level (e.g. recognizing names or parts of speech).

[3]2022, Dictionary.com

[4]Depending on the use case, almost any arbitrarily long sequence can be represented as a vector or matrix

A sliding kernel, or filter, moves along the dataset and performs dot product aggregations. With an (word) embedding dimension d, sequence (sentence) length l, and a filter of size $s \times d$ this would amount to a feature vector of size $l - s + 1$. The weights of these filters are trained, and many same- or different-sized vectors can be applied to tease out features of the text at different scales. After an activation function, a pooling operation (often a *max* or *mean* function) is applied to the activated feature vectors to obtain scalar values which are then concatenated. From this an output layer (e.g. a fully-connected layer) can be used to classify the text into a set of categories.

Convolutional networks are not fully-connected, but are feed-forward.

2.2.3 Recurrent neural networks

> [3]**Recurrence** [ri-**kur**-*uh*ns] *(noun)*
> *return to a previous condition, habit, subject, etc.*

Recurrent neural networks involve feeding in data consecutively, one word after another, to build a representation that takes all previously seen data into consideration (a kind of memory). In Figure 2.3 x_t is the t'th word embedding in a sequence and h_t and o_t are the hidden (memory) and output states at time t, respectively. Because datapoints are fed in one-by-one recurrent neural networks are particularly useful for word-level predictions, unlike convolutional neural networks.

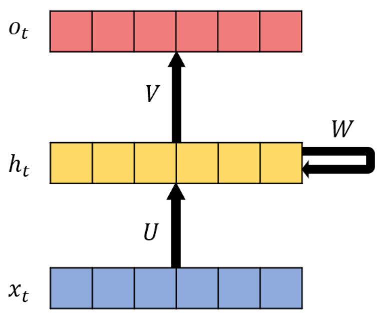


Figure 2.3: A vanilla recurrent neural network, where $h_t = \sigma(Ux_t + Wh_{t-1} + b_1)$ and $o_t = Vh_t + b_2$

Languages do not always flow in one direction; there are oftentimes words that depend on, or refer to, words to the left or to the right. In the phrase "I love the pho, it tastes so good", *it* comes after and refers to *pho*, a backwards reference. While in "I love it, the pho tastes so good", *it* comes before and refers to *pho*. In the second example, if we ingest data left-to-right, we won't know what *it* refers to until we see *pho*. Fortunately in recurrent networks data can be fed in left-to-right, but the reverse is also true, as is bidirectionalism in more sophisticated models.

A major flaw with traditional recurrent networks is that remnants of all data seen are preserved in memory forever. Long-range dependencies are difficult to capture as knowledge is accrued sequentially; the memory of long-ago data may be overwritten by more recent observations. Several recurrent architectures brought to market useful text generation by employing *forgetfullness*, where datapoints that are deemed unimportant are forgotten in memory, notably long short-term memory (LSTMs) and gated recurrent units (GRUs).

Recurrent neural networks may be fully-connected, but are by definition not feed-forward.

2.2.4 Pitfalls of foundational architectures

While the above architectures are powerful in their own right, some attributes prevent either widespread practicality or their ability to demonstrate a deeper knowledge of language. However, vestigial elements of them are seen in newer evolutions of NLP architectures: most notably are parallelizability and a more robust understanding of how to use the surrounding data.

Convolutional neural networks are excellently parallelizable. Taking advantage of the ability of modern graphics hardware to handle large amounts of processes in parallel, each filter can be executed simultaneously. This drastically reduces not only computational complexity at inference time but, perhaps more impactful on widespread use, at training time. With greater efficiency larger models can be trained on larger datasets resulting in a higher ability to generalize on new data. Yet in convolutional networks all data points are considered equally, a potentially negligent assumption.

Recurrent neural networks have a greater understanding of time. They are better able to capture dependencies at arbitrary lengths. Yet, all previously seen data affects the current state. This results in high computational costs to backpropagate the loss function for very long sequences. Additionally, the farther back in time a point is, the lower it influences the current state and a potentially vanishingly small gradient may result. Although less important data may be forgotten in some networks, they too lack a sophisticated mechanism for weighting the importance of previously seen data on new predictions.

2.3 Transformers

Models emplying transformer architectures have achieved widespread use via transfer learning, where a model or parts of a model are trained on a very large dataset (often comprised of multiple domains) toward a general task, and then later fine-tuned on a smaller, domain-specific dataset for specialized, downstream tasks.

The size of models has proven to be equally, if not more, important than training procedures showing that larger models typically outperform than smaller models.

Key	Value
0.097	0.288
0.378	0.931
0.442	0.457
0.036	0.593

Figure 2.4: A sample database

Though, distillation procedures have revealed smaller models with minimal performance loss [12].

The core concepts behind transformers are attention and autoencoders.

2.3.1 Attention

To address the issues with recurrent and convolutional networks, researchers began developing architectures that pay attention [5]. That is, they are highly influenced by important data and lowly influenced by less important data. In the case of translating the Swedish phrase "Jag kan inte lämna, min granne är utanför"[5] to English, you do not need to pay attention to *Jag kan inte* (I cannot) to translate *min* (my). The goal of attention is to find how much every other word is relevant to a certain word (self-attention, Figure 2.5), much like dependency parsing.

In the case of transformers, self-attention is inspired by relational databases. A database consists of key-value pairs, and the user interacts it with by submitting a query. When the user submits a query, the database returns the value corresponding to the key that is most similar to the query. With a similarity measure of e.g. absolute difference, a user who submitted a query of 0 to the database in Figure 2.4 would receive a value of 0.593.

Obtaining self-attention is possible using dot-product (employing matrix operations) and additive attention (employing a feed-forward neural network), the former being much more efficient in practice. To obtain dot-product attention, the concatenated word embeddings $X_{l\times d}$ are multiplied by trainable query, key, and value matrices $W^Q_{d\times m}$, $W^K_{d\times m}$, and $W^V_{d\times m}$, respectively, to obtain $Q_{l\times m}$, $K_{l\times m}$, and $V_{l\times m}$.

Intuitively, Q is representative of the input sequence, V representative of the target output sequence, and K an encoded intermediate representation that ties Q and V together. In the case of Swedish-English translation Q is analogous to the Swedish sequence, K a sort of Swenglish representation, and V a mapping of the English words to K. For text generation, V can be next-word predictions.

[5] I cannot leave, my neighbor is outside

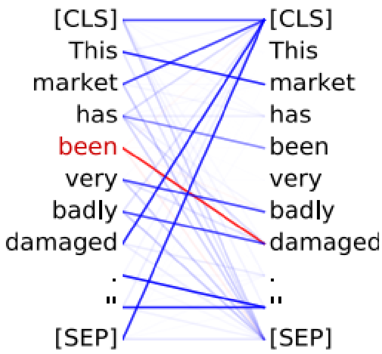


Figure 2.5: Illustration of attention in BERT [13].

$$Attention(Q, K, V) = softmax(\frac{QK^T}{\sqrt{m}})V \tag{2.1}$$

The values inside the dot-product resultant matrices Q and K may get very large, so the authors of [5] divide by $\sqrt{m}$ to reduce the variance and avoid small-gradient regions of the softmax function.

Multiple instances of W^Q, W^K, and W^V can be instantiated and trained to support the model in learning information from different representation subspaces at different positions, i.e. to "read between the lines".

$$MultiHeadAttention(Q, K, V) = \begin{bmatrix} head_1 \\ ... \\ head_h \end{bmatrix} W^O \tag{2.2}$$

$$head_i = Attention(QW_i^Q, KW_i^K, VW_i^V) \tag{2.3}$$

2.3.2 Autoencoders

Autoencoder, or encoder-decoder, architectures project the input onto an intermediate, condensed representation from which a decoder is able to make accurate predictions. This distillation finds efficient codings without the need for corresponding labels. They are often trained by learning to find an intermediate representation, or latent space, that can be used to accurately reconstruct the original input.

The decoder is only useful in conjunction with the encoder, however the encoder alone can be incorporated into larger architectures to assist in denoising and dimensionality reduction. This can improve downstream computational efficiency and performance of the model it comprises.

2.3.3 BERT

Bidirectional Encoder Representations from Transformers [6] is a transformer model developed by Google. It is almost identical to the encoder-decoder architecture pro-

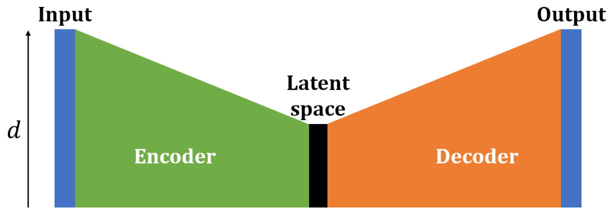


Figure 2.6: Encoder-decoder dimensionality reduction, d is the dimension size

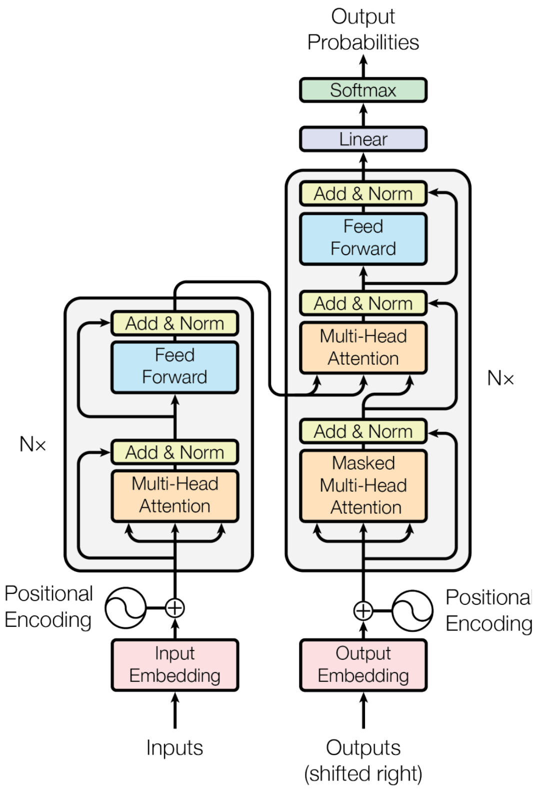


Figure 2.7: The transformer architecture proposed by Vaswani et. al.

posed in [5], Figure 2.7. The encoder is on the left, and the decoder on the right. Feed forward layers are used to reduce or expand the dimensionality of the attention-informed embeddings.

Because the transformer involves no convolutions or recurrence, it is necessary to inject some information about the relative and absolute positions of the tokens. The positional encoding methods impose a fixed-length input sequence limit on the model (512 tokens in this thesis) and so, unlike recurrent and convolutional networks, the inputs in these models must be truncated to this limit.

BERT was trained with two objectives: **masked-language modelling**, where a small percentage of tokens are masked (replaced with a special masking token) and the model is trained to correctly identify the masked token, and **next-sentence prediction**, where the model decides from two sequences which came first.

The encoder portion of BERT is invaluable in transfer learning as it is able to construct a contextual, subword- (called word pieces, e.g. perfect-ly, pre-view) level representation of text. BERT has received praise in document classification [8] and named-entity recognition [9], and evidence has shown that it self-discovered well-known, manually applied NLP methods used prior to its inception [10]. Several sizes of pretrained BERT models are available for download, ranging from 66M to 340M parameters.

Due to its bidirectional nature, BERT is not suitable for generating text.

2.3.4 GPT

Generative Pretrained Transformers are autoregressive models, meaning their outputs are fed back in as inputs, and are most demonstrably used in text generation. They have achieved prowess in writing poetry, computer code, stories, question answering, and many other generative tasks. Since GPT-1's 2018 inception by OpenAI [11], later iterations have grown vastly in size, from 82M parameters to over 175B.

The models are trained on unlabelled text corpora to recreate a sequence. Given their autoregressive configuration, that means given the input phrase "I make the best räksmörgås" to generate "I", then use "I" to generate "make", then use "I make" to generate "I make the", and so on. In technical terms, to learn the conditional probability of language $p(w_i|w_0, w_1, ..., w_{i-1})$, also known as language modelling.

To generate text, GPT models take in a sequence and predict what comes afterwards. As with BERT, they are limited in length (512 tokens in this thesis).

3

Reinforcement Learning

Laban et. al. [2] proposed a modular, unsupervised abstractive summarization model to generate news headlines using reinforcement learning. The Summary Loop contains a GPT model to generate the summaries, a GPT model to evaluate the `fluency` of the generated summaries, and a BERT model to evaluate the degree to which the summary `covers` the main points of the article.

The summarizer model (GPT) is initially trained to extract the first part of an article which, in the news domain, is often a strong baseline summary, [3] and [4]. LEAD-3, the first three sentences of an article, is common. The authors employ a modification, the first K characters.

The fluency model (GPT) is trained on the domain, in this case news text, and later frozen. Its purpose is to judge if a generated summary reads, sounds, and appears like target summaries. A scaled version of the negative log probability $NLP(\vec{w}) = -\sum_{i=0}^{|\vec{w}|} \log[p(w_i \mid w_0, ..., w_{i-1})]$ of a generated summary $\vec{w}$ is taken as the fluency score.

$$FluencyScore(\vec{w}) = 1 - \frac{NLP(\vec{w}) - LP_{low}}{LP_{high} - LP_{low}} \tag{3.1}$$

where LP_{low}, an ideal value, and LP_{high}, a maximal value are chosen so that the FluencyScore usually lies on $[0, 1]$, but is allowed to negative for very out-of-distribution summaries.

The coverage model (BERT) is trained on concatenated (document, summary) pairs with the goal of filling in masked tokens from the document, and later frozen. For full unsupervision [2] uses the first K characters of the article as the summary.

To identify the main points of an article, the authors employ TF-IDF[1]. The top k words, as ranked by TF-IDF, are masked from the document, and the model consecutively ingests two inputs: (`summary`, $[SEP]$[2], `masked document`) and (`masked document`). The motivations is that if the model is able to correctly fill in a masked token using the summary, but cannot without it, then its likely that this information

[1] $TFIDF(D, w) = tf(D, w) \cdot log(N/df(w)) + 1$ where $tf(D, w)$ is the number of times word w appears in document D, $df(w)$ is the number of documents w appears, and N is the number of documents

[2] $[SEP]$ is a special separator token

was included in the summary even if the masked token itself does not appear in the summary.

Then, the proportion of correctly filled masks $accuracy(\vec{p}, \vec{t}) = \frac{1}{k}\sum_{i}^{k} 1 \cdot (p_i = t_i)$, where $\vec{p}$ are the predicted tokens and $\vec{t}$ are the targets, without the summary (i.e. with `masked document` as input), is subtracted from the proportion of correctly filled masks with the summary included in the input. The result is taken as the coverage score. For a summary $\vec{w}$ of document $\vec{D}$ the coverage score is calculated as

$$CoverageScore(\vec{w}, \vec{D}) = accuracy(\vec{p_s}, \vec{t}) - accuracy(\vec{p_\emptyset}, \vec{t}) \tag{3.2}$$

where $\vec{p_s}$ are predicted tokens with (`summary`, $[SEP]$, `masked document`) as input and $\vec{p_\emptyset}$ are predicted tokens with (`masked document`) as input.

Additionally, several so-called *guardrails* are introduced during training to deter the model from clever and undesired solutions to reward maximization. These include a pattern penalty pen_{pat}, where a penalty is imposed if the summarizer generates summaries with n-gram occurrences above a certain threshold over recent summaries, a repeat penalty pen_{rep}, where frequent repetitions of words or n-grams in the same summary are penalized, and a length penalty pen_{len}, where very long and/or very short summaries are penalized.

$$SummaryScore_0(\vec{w}, \vec{D}) =$$

$$\alpha FluencyScore(\vec{w}) + \beta CoverageScore(\vec{w}, \vec{D}) - \sum_{i \in (pat, rep, len)} \gamma_i pen_i \tag{3.3}$$

where α, β, and γ_i are importance weighting hyperparameters.

For loss propagation, the authors employ self-critical sequence training. Two summaries for each document are generated: a summary drawn from the distribution of next-token probabilities (sampled), and a summary where the most likely next token is always chosen (greedy). Then, the loss function is

$$L = (R^g - R^s) \sum_{i=0}^{N} \log p(w_i^s | w_0^s, ..., w_{i-1}^s, \vec{D}) \tag{3.4}$$

where R^g and R^s are summary scores for the greedy and sampled summaries, respectively, w_i^s is the i'th token of the sampled summary, and $\vec{D}$ is the article. If $R^s \geq R^g$, minimizing L maximizes the likelihood of the sampled sequence and increases expected reward of the model.

In simpler terms we move the model in the direction of whichever summary received a higher score. The distance moved is proportional to the score difference.

4

Dataset

Provided by the company were 105K ad copies and their associated key performance indicators in addition to thousands of real estate webpages, of which about 50K listing descriptions were parsed. The dataset consists of English listings and ad copies from the US, the UK, Ireland, Australia, and New Zealand.

4.1 Cleaning and Preprocessing

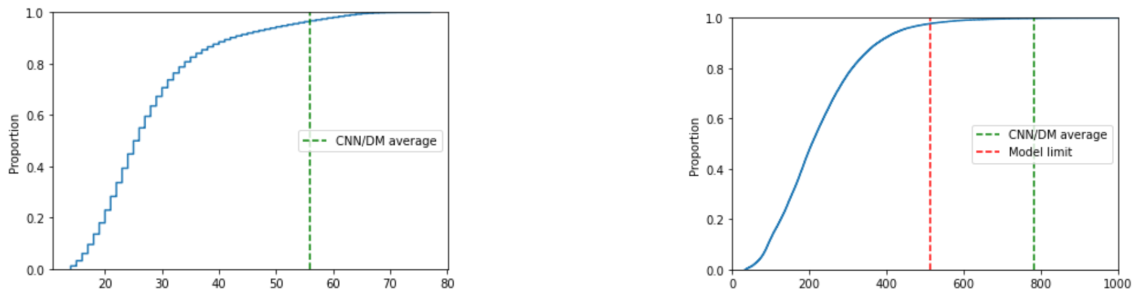
Many real estate companies incorporate standardized messages into their listing descriptions, such as Covid-related warnings, slogans, "Contact us today to book your appointment", etc. These appeared inconsistently and were not always consistent themselves. They were removed by inspection from both the parsed descriptions and ad copies, directed by bigram relative frequency within same-company listings.

Phone numbers, email addresses, and URLs were removed with regular expressions. Repeated occurrences of punctuation were replaced with a single occurrence, and fully-capitalized sentences, emoji characters, and superfluous whitespace characters were likewise removed.

It should be noted that extensive verification of the cleaning could not be completed. Noted potential issues include missing special characters (e.g. `Caf?` instead of `Café`, likely due to encoding issues while storing the raw HTML files), nonstandard formattings (e.g. bulleted lists delimited by `-`, `*`, `?`, or `-`), misspellings, and inconsistencies regarding capitalization (e.g. headline appearing in the description) and abbreviations. Website-specific coding within the parsed field (e.g. boldfaced by wrapping in `?`) could not be removed at scale.

4.2 Comparison with CNN/DailyMail dataset

[2] uses the CNN/DailyMail dataset, which contains about 300K articles (with 781 tokens on average) and their corresponding human-written headlines (56 tokens on average). Notably this dataset contains human-written summaries, whereas in the ads dataset the summaries are extracted from the listing itself. Also, the articles are very well-structured and proofread; they contain few, if any, incongruities or grammar, spelling, and punctuation mistakes.



(a) Ad copies **(b)** Listing descriptions

Figure 4.1: Cumulative distributions of the number of tokens in the texts

5

Methods

Due to limitations imposed by social media platforms, as well as best practices within the company and those inherent to fixed-length transformer models, the length of generated ad and listing text must be restricted. Given that almost 90% of ad copies were less than 40 tokens, this limit was imposed on the generated text. The first 472 tokens of listing descriptions were taken as input considering the models' sequence limit of 512 tokens.

Resource constraints necessitated the use of distilled versions of GPT-2 (`distilgpt2`, 82M parameters) and BERT (`distilbert-base-uncased`, 66M parameters). Both were implemented using the `transformers` Python library provided by Huggingface.

All models were trained on a single RTX 2070 Super GPU with 8gb of video RAM.

5.1 Data segmentation

To validate the pretrained models' abilities to generalize on new data, $10K$ description-ad pairs were randomly selected and reserved. What remained was about $90K$ ads to pretrain the fluency model and $40K$ listing descriptions to pretrain the coverage model and summarizer. The reserved data was used as a validation set for pretraining, and as the training set for training with reinforcement learning.

5.2 Pretraining the summarizer

The summarizer was pretrained in two different ways for later experiments. In both cases, a learning rate of $2e-5$ was used and the rest of the training procedure remained consistent with Section 5.3 unless otherwise noted.

5.2.1 Laban et. al.

Like in [2], the summarizer was pretrained by training the model to copy the first 40 tokens of a sequence. The authors note that in this way, the summarizer begins with a strong baseline summary for news articles, and we note the similarity to the extracted ads in this domain[1]. Specifically, it was first finetuned as a language model and then trained for 3 epochs to copy.

[1]Recall that the ad text is almost always a truncation of the first part of the listing description

5.2.2 Language model

In this approach we only pretrain the summarizer to model the language of the domain.

5.3 Finetuning frozen models

Both the fluency and coverage models, which contribute to the reward given to the summarizer, were trained and frozen. An effective batch size of 32 was used and the models were optimized via the `Pytorch` implementation of the `AdamW` optimizer. Early stopping was implemented, where the model with the lowest cross entropy validation loss during training was chosen. Resource constraints prevented cross-validation, see below for training times and Appendix 1 for training plots. The elements in this section hold for all experiments.

5.3.1 Fluency

The GPT-2 model (initialized as `distilgpt2`) for evaluating the fluency of generated copy was trained to model the language of ads that ran in advertising campaigns. A learning rate of $5e-5$ was used[2]. The model took nearly 3 days to converge.

5.3.2 Coverage

The BERT model (initialized as `distilbert-base-uncased`) for evaluating the degree to which the generated text covers the main points of the listing was trained on the first $K = 100$ tokens of the listing concatenated with the first 412 tokens of the masked listing, with a learning rate of $2e-5$. Although it will use summaries of length $K = 40$ to evaluate generated summaries, the extracted summaries (description[: K]) used in pretraining must contain sufficiently many masked tokens to be useful. It was noted that compared to the CNN/DailyMail dataset, the TF-IDF masked tokens appear significantly later our dataset. About 50% of documents in the CNN/DailyMail dataset had 6 or fewer TF-IDF masked tokens that appeared in the first 40 tokens of the document, compared to 3 in ours.

5.3.2.1 Masking procedures

Several masking procedures were experimented. To maintain consistency with [2], 12 distinct tokens were masked in all cases.

5.3.2.1.1 TF-IDF As a baseline, the default masking scheme of term-frequency inverse-document frequency used in [2] was tested using the `TfidfTransformer()` method from `scikit-learn`.

[2]Although lower learning rates hedge against catastrophic forgetting, a lower learning rate at the expense of longer training times was deemed impractical

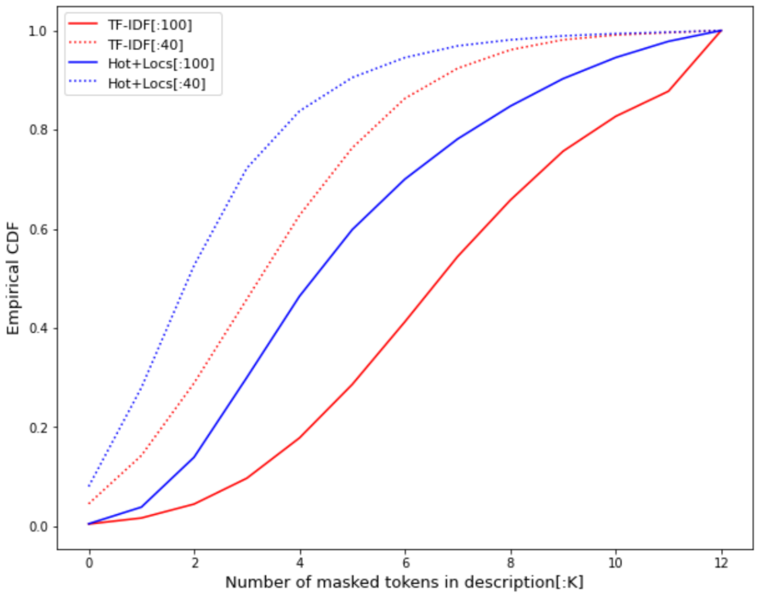


Figure 5.1: Number of masked tokens appearing training dataset descriptions, truncated to $[: K]$

5.3.2.1.2 Hot words + locations Because of the distinct domain of online real estate advertising, a degree of homogeneity is desired to exploit known qualities that garner clicks. To identify so-called "hot" words, the number of clicks garnered by ads that featured each word were tallied up and ranked, keeping only the nouns, adjectives, and adverbs. The decision to include only these parts of speech was made to keep the masking procedure relevant to features of the property and words that describe them. Using a statistic like the average or median number of clicks yielded unfavorable results, likely due to other impactful elements such as location and Facebook's advertising optimizations.

Although the resulting words (Table 5.1) were relevant, the result was not unlike selecting the most frequent words in the corpus. Regardless, the motivation is to exploit BERT's attention mechanism. By masking these words, we encourage the summarizer not only to use them but to also use words nearby in the statement's dependency tree. Consider the masked document

This modern 3-bedroom home boasts a ~~renovated~~ kitchen and ~~large~~ master bathroom.

To maximize coverage score, a generated ad should contain the dependency information *renovated* $\rightarrow$ *kitchen* and *large* $\rightarrow$ *bathroom*. A generated ad such as *Renovated home with large kitchen and modern bathroom* would likely yield a low coverage score even though it contains the masked words. On the other hand, *Featuring a large bathroom and renovated kitchen* would yield a higher score.

Location is also a relevant feature of properties. A `bert-base-cased` model designed for name-entity recognition and fine-tuned on the CoNLL-2003 Named Entity Recognition dataset, `dslim/bert-base-NER` provided by Huggingface was employed

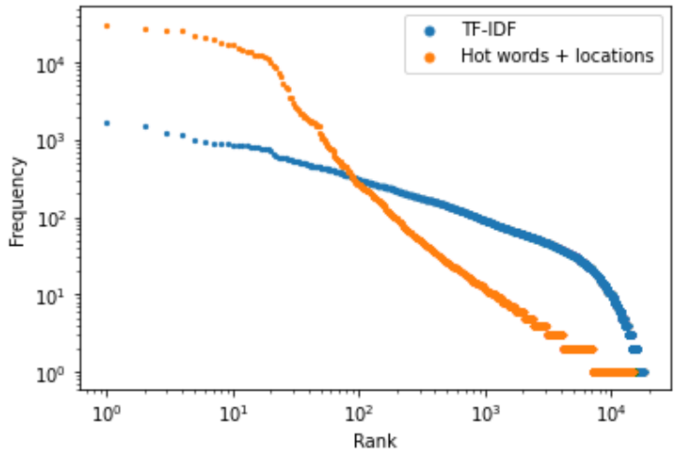


Figure 5.2: Rank-Frequency plot for masked tokens

to mask locations from the listing description. The first two locations, if any, with an accuracy score $\geq 75\%$ were masked and took priority over hot words. About 75% of descriptions had one or more identifiable locations and 58% had two or more.

Word	Hot Rank	TF-IDF Rank
home	1	4
family	2	1
bedroom	3	102
property	4	3
living	5	103
high	50	165
gorgeous	100	368
immaculate	200	761
endless	500	1703

Table 5.1: Example of masked tokens by frequency ranking

5.4 Summary Score modification

Because the summary score 3.3 uses the sum of fluency 3.1 and coverage 3.2 scores, it is possible that the summarizer will learn to maximize one at the expense of the other. For example if the distribution of reference summaries differs significantly from the source documents, embedding information from a document may yield a coverage reward at the expense of fluency. To mitigate this risk, as well as reduce the number of hyperparameters, experiments using the product of these values were investigated.

$$SummaryScore_1(\vec{w}, \vec{D}) =$$

$$\rho FluencyScore(\vec{w}) CoverageScore(\vec{w}, \vec{D}) - \sum_{i \in (pat, rep, len)} \gamma_i pen_i \tag{5.1}$$

To maintain similar effects of the penalties relative to the summary score, we choose ρ so that the unpenalized, modified summary score $SS_1 = \rho cf$ is not unlike the original $SS_0 = \alpha f + \beta c$ (where f and c are the fluency and coverage scores, respectively). Because the coverage and fluency scores $\in [0, 1]$, their product will nearly always be less than their sum. If we take $\rho = \alpha + \beta$, although the resulting scores $(\alpha + \beta)cf$ & $\alpha c + \beta f \in [0, \alpha + \beta]$, the former will almost certainly be lower. Since future fluency and coverage scores are dependent on previous summary scores, an ideal value cannot be determined empirically and discretion was taken to choose $\rho = 50$.

5.5 Penalties

Similarly to [2] length, pattern, and repetition penalties were employed. In all cases, the penalty value $\in [0, 1]$ is scaled by a weighting factor γ_i. The Python library `NLTK` was used to tokenize the generated text into words.

5.5.1 Length

A penalty of γ_{len} was imposed on any summary that exceeded 40 word-piece tokens or contained fewer than 20 words. This choice was made to prevent long summaries, as well as summaries with few words but sufficiently many word-piece tokens.

5.5.2 Pattern

If a bigram (of words) appearing in a generated summary also appeared in more than 25 of the 50 most recent summaries generated during training, then a penalty of γ_{pat} was imposed. This was made to discourage the summarizer from uncreative or "one-size-fits-all" summaries.

5.5.3 Repetition

Since repetition is a common issue in neural text generation, a penalty of γ_{rep} was imposed on a summary if its most frequent word was used more than 20% of the time or its most frequent non-stop word was used more than 10% of the time. Using word-piece tokens here is unfavorable as it may unfairly punish the summarizer for appropriately using word-pieces like -ly, pre-, and -ed.

5.6 TextRank

Rather than selecting the first part of the listing description as the ad text, a robust and computationally cheap alternative for the company is to employ an extractive summarization tool.

Extractive summarization is the process of summarizing a document by extracting only the most salient sequences from the document, and then grouping them in a coherent manner. A notable algorithm for this is TextRank [15], inspired by the PageRank algorithm developed in Google's early years.

TextRank operates under the assumption that sentences which have many terms in common with other sentences must be important. It works by forming a directed graph of sentences in a document and the edges between these vertices, the similarity, is a measure of overlap between the two sentences. It is expressed as

$$S_{ij} = \frac{\sum_{k=0}^{N} w_k \in V_i \& w_k \in V_j}{log(\mid V_i \mid) + log(\mid V_j \mid)} \tag{5.2}$$

where V_i and V_j are sentences and w_k is the k'th unique (non-stop) word from both sentences. The denominator exists to control for very long sentences.

The score of a node is calculated as

$$Score(V_i) = (1 - d) + d \sum_{V_j \in IN(V_i)} \frac{S_{ji}}{\sum_{V_k \in OUT(V_j)} S_{jk}} Score(V_j) \tag{5.3}$$

where $IN(V_k)$ and $OUT(V_k)$ represent the set of vertices which have a connection into and out of vertex V_k, respectively, and d is a damping factor. This score calculation is iterated over the graph until convergence is reached. In our implementation convergence is reached when the squared difference of all vertices' scores change < 0.001. As in [15], $d = 0.85$.

To create a summary from the scored sentences we concatenate them together. If the highest scoring sentence exceeds the character limit imposed by the social media platform, it is truncated. Otherwise, we add sentences in decreasing score order until the character limit is reached.

6

Generating ad copy with reinforcement learning

Three checkpoints, equally spaced, were taken during every epoch while training with reinforcement learning. If the average sampled score in this checkpoint was $> 30\%$ worse than the highest average score so far, the model and optimizer were reverted to this checkpoint. If it was better than the highest checkpoint score then the model and optimizer were saved for later reversion. This was done because in reinforcement learning, the model generates it's own training data. As long as the model is improving, it equips itself with progressively better training data. If performance decreases (due to e.g. poor exploration, hyperparameters, or input data), future generated data may be inadequate for later recovery.

The time per epoch was around 1 hour and each experiment was run for 25 epochs. A learning rate of $2e-5$ and effective batch size of 33 were used.

6.1 Experiments

The experiments conducted vary in three ways: the summarizer pretraining procedure (Section 5.2), the coverage scheme (Sections 5.3.2.1.1 and 5.3.2.1.2), and the summary score formula (Section 5.4).

In all experiments, the values for LP_{low} and LP_{high} in Equation 3.1 were taken as 0 and 10, respectively, as in [2]. Additionally $\alpha = 2$, $\beta = 20$, $\gamma_{len} = 2$, $\gamma_{pat} = 5$, and $\gamma_{rep} = 2$.

6.1.1 TF-IDF

Two experiments were conducted using the TF-IDF coverage scheme: one employing the default scheme as in Laban et. al., and one employing a modification to the summarizer pretraining. Both experiments employ the original summary score formula (Equation 3.3).

6.1.1.1 Experiment 1A: Laban et. al.

For a direct comparison on a new dataset, the Summary Loop was applied as reported in [2]. The summarizer was pretrained to extract the first 40 tokens of the description as in Section 5.2.1.

6.1.1.2 Experiment 1B: Modified summarizer pretraining

To rectify an issue encountered with the previous experiment, the summarizer was instead pretrained to model the language of listing descriptions (Section 5.2.2). Similarly, the original summary score and TF-IDF coverage scheme were used.

6.1.2 Hot words + locations

Two experiments were conducted using the new coverage scheme designed for this domain, Section 5.3.2.1.2. Both experiments employ a summarizer pretrained to model the language of listing descriptions.

6.1.2.1 Experiment 2A: Hot words

In this experiment the original summary score, Equation 3.3, is used.

6.1.2.2 Experiment 2B: Hot words + modified summary score

This experiment utilizes the product of fluency and coverage scores, Equation 5.1.

7
Results

Because the reference ads provided by the company are usually a truncation of the document in question, Rouge scores represent a measure of similarity (or novelty) compared to the existing baseline approach. As a measure of reference, Rouge scores for ads that ran in advertising campaigns compared to the first 40 extraction are below. Appendix 2 contains a table of summaries generated for out-of-dataset descriptions, compared with the company's baseline and TextRank.

All figures a simple moving average of 5000 (over minibatches) was used. In below Rouge calculations, the text was generated via sampling from the next-token distribution.

In each experiment section, text generated after training are shown for four different listing descriptions. Each text has a number, and this number corresponds to a particular listing description[1].

Rouge-1	0.62
Rouge-2	0.55
Rouge-L	0.61

Table 7.1: Rouge F1 scores for ads that ran in advertising campaigns compared to the first 40 tokens extracted from the corresponding listing description, on the reserved dataset

	Reference ads	Description[:40]	Description[:100]
Fluency	0.93	0.57	0.46
TF-IDF Coverage	0.18	0.27	0.47
Hot + Locs Coverage	0.07	0.10	0.21

Table 7.2: Average fluency and coverage scores for reference ads and truncated listing descriptions, on the reserved dataset

[1]The descriptions are not provided due to privacy concerns

7.1 Experiment 1A

With the summarizer pretrained to copy the first 40 tokens of the description, the model never ventured onto other summary score maxima. In fact, after 25 epochs the F1 scores for Rouge-1, Rouge-2, and Rouge-L for the resulting summaries compared to the first 40 extraction were all about 0.96.

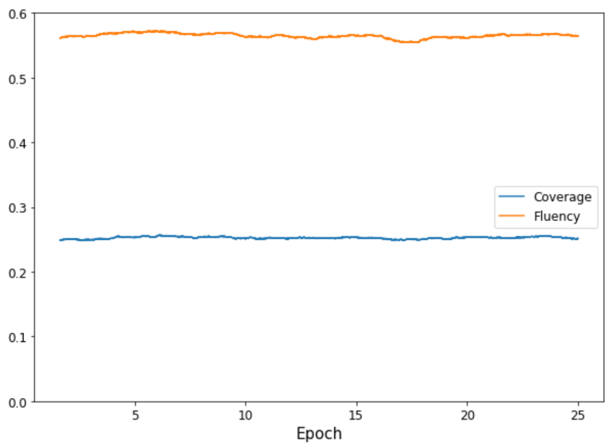


Figure 7.1: Fluency and coverage scores for Experiment 1A

7.2 Experiment 1B

With the summarizer instead pretrained to model the language of listing descriptions, the fluency and coverage scores in this experiment did not stagnate. Normalized coverage scores averaged about 0.17, indicating it embedded significant information from the listings into the generated ads. A noted issue in its output was repetition, which probably contributed to its relatively low fluency score.

1. Located in the Sandarra Estate, the moment you open the front door, you are greeted with high ceilings coupled with a light and bright contemporary home located in the highly sought-after Sandar

2. Located to the front of Collinswood, No. 238 Collinswood has been well maintained over the years and a super 3 bed semi-detached residence perfectly positioned to the rear of the development has
3. Located 4 bedroom semi-detached property for sale on the outskirts of Ballina town in Ballina town in Ballina town in Rath Dubh, Rehins Fort development has a bright 4
4. Located on Killick Creek of Killick Creek, Killick Creek has been a new owner's right, literally a stones throw to the beautiful Killick Creek of Crescent Head, this 2 bedroom 1

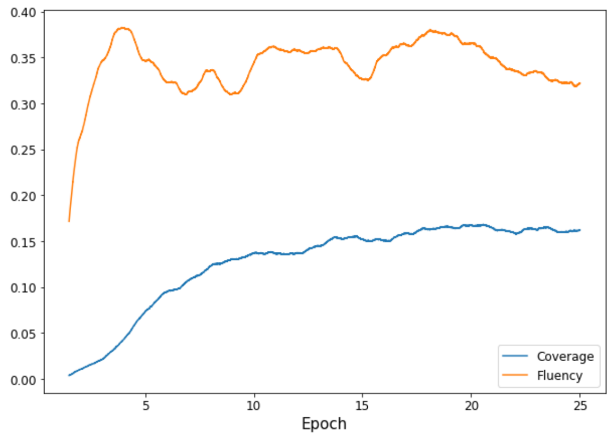


Figure 7.2: Fluency and coverage scores for Experiment 1B

	Reference ads	Truncated descriptions
Rouge-1	0.47	0.60
Rouge-2	0.35	0.49
Rouge-L	0.44	0.58

Table 7.3: Rouge F1 scores for experiment 1B

7.3 Experiment 2A

Here, hot words and locations are masked instead of TF-IDF like the above experiments. The coverage scores in this experiment were remarkably low. Consequently, the generated ads suffered from a lack of relevance to the property in question. However, the fluency scores were slightly higher than Experiment 1B. The generated text often contains words that are frequent in real estate ads, but it does not sound very human.

1. This is your chance to secure your opportunity to purchase this great home country family home, ready to move in to make this great home, is this great family home ready to move in to!Located

2. This stunning family home is here to book your inspection, please call us to book your inspection.Located in good good order schools are nice to say hello to this isThis is your opportunity to purchase

3. This home is ready to make this book sale, here is your chance to purchase! Please contact us to book your inspection - please contact us to book your inspection. Please contact us to arrange your

4. This is your chance to purchase this great home that is for you to purchase!Please contact us to book your inspection, contact us to book your inspection today! Please contact us to book your inspection

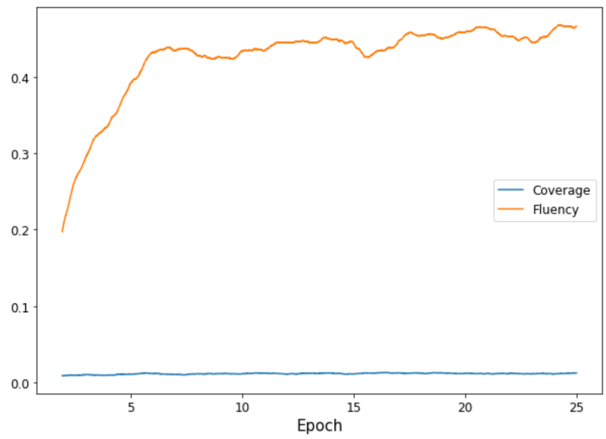


Figure 7.3: Fluency and coverage scores for Experiment 2A

	Reference ads	Truncated descriptions
Rouge-1	0.11	0.12
Rouge-2	0.06	0.01
Rouge-L	0.10	0.10

Table 7.4: Rouge F1 scores for experiment 2A

7.4 Experiment 2B

Here, we employ the modified summary score while retaining the new masking procedure from the previous experiment. The coverage and fluency scores were both poor in this experiment (especially the latter). Because the summary score is a function of the product of these two scores, a higher score is only achieved if one or both scores improve. Therefore, the model is only encouraged to explore them simultaneously.

1. Located is situated to enjoy the unique opportunity to make your own personal style to appreciate the value or potential value have a better idea. Why? You may make this personal decision to get a better value

2. A.A is simply to learn about the primary has a better value is to know about the benefits of living or make this to make an alternative. It is eligible to have a private or investment

3. Welcome for an decision is to seek a good value value to know about the privacy is. If you know what is looking about the updated has been able to appreciate the updates! This is updating to

4. Located, you can understand the alternative to obtain a potential investment or access makes a personal decision to make. There is an opportunity to make a better idea to take a possible opportunity to verify. More

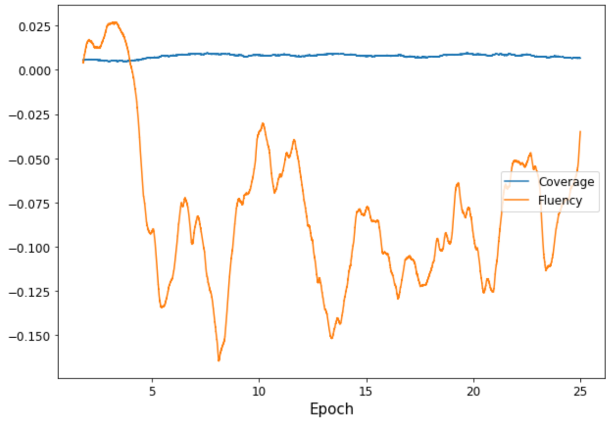


Figure 7.4: Fluency and coverage scores for Experiment 2B

	Reference ads	Truncated descriptions
Rouge-1	0.11	0.12
Rouge-2	0.00	0.00
Rouge-L	0.09	0.10

Table 7.5: Rouge F1 scores for experiment 2B

8 Discussion

8.1 Decoding algorithms

Part of the reason neural networks have received so much attention in recent years in regards to text generation is in decoding methods. The two discussed in this thesis are sampling (from the language model's distribution of next-token probabilities) and greedy (always choosing the most likely next token). Other decoding methods, such as beam search and top-K sampling, often result in higher quality text. This should be considered when examining the supplied texts in Appendix 2, as they were generated via vanilla sampling.

To generate the most likely sequence, the one the model is most sure should come next, we need to explore all paths along the distribution of next-token probabilities. This is often impractical given the vocabulary size of word-piece tokenizers and the length of text sequences.

Beam search aims to prevent the unfortunate event of choosing a poor next token. Whereas we follow a random walk with vanilla sampling, here we look at all possible paths after choosing the b most likely tokens, and choose the token corresponding to the most likely path. This minimizes the likelihood of the model choosing a next token that is very likely but, when autoregressively fed back into the model, results in high perplexity.

In top-K sampling we effectively disregard the least likely k tokens, marking their probabilities as zero. We then normalize the resulting array to sum to 1, and sample from this distribution. This minimizes the likelihood of choosing a next token that is very unlikely.

Other methods, like temperature, change the flatness of next-token probability distributions. An ensemble of these decoding algorithms can be used to create a suite of high-quality, generated text for use in A/B testing.

8.2 Exploration

Due to the company's parser, the ad text that appears on social media is often the first part of a listing description. This essentially results in both the fluency and coverage models being finetuned on this truncation and, consequently, this sequence yielding high fluency and coverage scores. If we initialize the model to reproduce this sequence it is motivated not to explore novel summary score maxima, but to correct any mistakes it made when copying. This lack of exploration is likely due to the use of self-critical sequence training, where the loss function is a function of the difference between two summaries' scores: one of a summary drawn from the distribution of next-token probabilities, and one whose most likely next token is always chosen. Without learning an estimate of expected future returns, the model is limited to it's current distribution. If it is a high scoring distribution then the distribution is further maximized, further decreasing it's likelihood to explore new maxima. As such, the results using other policy estimation methods may differ. During early pretraining experiments, lower learning rates and fewer epochs were tested with similar results.

8.3 Coverage score

The coverage score (3.2), calculated as the masked language modelling accuracy with the summary and masked document as input minus the accuracy with only the masked document as input, encourages the model to include masked information in the summary. If the coverage model is able to to fill in the masked tokens based on the document alone, this incentive disappears. Consider the document-summary pair:

"Last week she went to the ______ to check out the new Harry Potter book"
$[SEP]$
"She went to the library"

A sufficiently trained BERT model would not need the summary to identify *library* as the masked token, yielding no coverage reward for this summary. The incentive is contingent on a sufficient difference between the accuracies from the two inputs, which is dependent on the masking procedure and corpus.

It is probably for this reason that the authors of [2] select TF-IDF as the masking procedure. Words scoring highly in TF-IDF are thought to be particularly important to the document in question. In news articles these are often names, locations, and events; words that when masked typically require context (provided by the summary) to correctly fill in. With a coverage scheme masking tokens that are easier to infer, such as hot words, the normalized coverage scores will be systematically lower (Table 8.1). If 75% of $k = 12$ masked tokens can be filled in without the summary, then the model can only get a coverage reward for embedding $\frac{3}{12} = 25\%$ of the masked information in its summary. Some ways to override this inherent deemphasis may include increasing the importance weighting β or scaling the normalized coverage score to $\frac{accuracy(\vec{p_s},\vec{t})-accuracy(\vec{p_\emptyset},\vec{t})}{1-accuracy(\vec{p_\emptyset}-\vec{t})}$.

However, these are only superficial solutions. It is apparent that the coverage scheme

Coverage Scheme	accuracy($\vec{p}_s$, $\vec{t}$)	accuracy($\vec{p}_\emptyset$, $\vec{t}$)	**CoverageScore($\vec{w}$, $\vec{D}$)**
TF-IDF	86%	40%	**0.46**
Hot words + locations	96%	75%	**0.21**

Table 8.1: Average coverage scores on the reserved dataset using the first 100 tokens of the description as a proxy summary. As in Equation 3.2, accuracy($\vec{p}_s$, $\vec{t}$) and accuracy($\vec{p}_\emptyset$, $\vec{t}$) are the percent of correctly filled masks with and without the summary, respectively.

must mask a significant amount of information that cannot be inferred from the document alone. This is a major limitation to the model when applied to this domain, as there is often high similarity in the relevant information (e.g. type of property, has a garage/backyard, is renovated, appliance material, etc.) between properties. In other words the information we want to bring into the summary is often in many listing descriptions, and the coverage model learns to infer this information from the document itself.

8.4 Summary score modification

Using the modified summary score did not yield significant improvements to the proposed coverage scheme. This is likely because the summarizer was not capable of including significant amounts of masked information in the summary, yielding little reward even if the summary was fluent. Another potential issue is that both the fluency and coverage scores are allowed to be negative. If they both are, the joint reward is positive, so in hindsight the coverage reward should have been run through a ReLU function. Restricting the The effects of this modification in conjunction with the TF-IDF coverage scheme were not tested due to time constraints.

8.5 Rouge analysis

Rouge scores are a measure of the overlap between a text and a reference, often used in machine translation. Rouge-1 and Rouge-2 measure the percent of overlap of 1- and 2-grams, respectively, and Rouge-L measures the longest matching sequence (longest common subsequence).

Although rouge scores are not necessarily useful for assessing how good a summary is, comparing the generated texts' scores to the company's baseline gives a decent assessment of similarity. Some level of similarity is expected, considering the documents are truncated to 471 tokens (due to fixed-length transformer limitations).

Both Experiment 2A and 2B, using the hotwords masking scheme, were extremely dissimilar. Considering how undesirable the generated text was, this was unsurprising. However Experiment 1B had more interesting results. With the truncated descriptions used as reference, the generated texts' scores were comparable to the advertisement text that appeared online. Yet, these scores differed from the scores obtained comparing the generated text to the advertisement text. This signals that the generated texts are similar to the truncated descriptions but dissimilar to the advertisement texts.

8.6 Hallucinations

In natural language generation, the term *hallucination* is often used to describe the inclusion of out-of-scope information. For example, a summary which talks about US President George Bush given a US news article from 2022. Or, for this domain, a summary that says there are three bedrooms when in reality there are only two. These are difficult to detect systematically, though surveys have been made [16]. The framework used in this thesis is subject to these concerns, as are other transformer-based neural generation frameworks.

8.7 Training dataset and time

Of the supplied web pages, it appears some were saved with improper encodings. Instances such as *Instantly appealing from its striking modern fa?ade, ...* within the listing description likely affected the coverage and fluency models' finetuning, and certainly affected the model outputs. Other issues include fully capitalized and run-on sentences, hyperlinks, phone numbers, Covid-19 warnings, and inconsistent standardization with itemized lists. Including phrases like this directly in the summary may yield a coverage reward at the expense of fluency, since these very seldomly appear in the online advertisements.

Additionally, the dataset was significantly smaller than the CNN/DailyMail dataset used in [2]. This likewise may have affected the results.

Total training time, including finetuning frozen models, was over one week. The choice to use 25 epochs was made as this roughly equated to one day of training, and time constraints prevented longer experiments. To reach true convergence, a near-zero loss or near-zero (near-one) log (true) probability of the summary generated via sampling could be considered.

Like other language models, the ones used in this thesis are subject to the biases present in its training data. Not limited to the data used in initial training, the data used here adheres to the norms and standards of American, Australian, Kiwi, Canadian, and British English. If the model were deployed as-is to another dialect, e.g. Singaporean English, the idiosyncratic differences would not be captured.

8.8 Model size

The size of models may have played a significant role in the results. Increasing the size of transformer models correlates with higher performance in nearly all natural language processing applications. The models used in this thesis are some of the smallest available, and are most often used for educational, not research, purposes. A larger number of parameters would likely contribute significantly to the generated text's readability.

8.9 TextRank

A major benefit of using an extractive summarization tool is that the text has a much higher likelihood of being coherent and free of the grammatical mistakes experienced in the experiments, since it was written by a human. It is computationally very cheap, and different summaries can be created by relaxing the ranking of sentences' scores. However ensuring that the sentences convey desired information is difficult, and the text is subject to data cleanliness concerns.

9 Conclusion

This thesis investigated the application of the summary loop, a modular framework for text generation, to the domain of online real estate advertising. The framework includes a generator and two models to judge the fluency of the generated text and the degree to which it covers relevant information from a source document. The generator is trained with reinforcement learning according to the scores it receives from the judge models, as well as user-defined penalties.

By employing the model taken directly from the paper authored by Laban et. al., it was shown that the framework is suitable for domains other than news articles as it was originally proposed. A new coverage scheme, designed for the domain of online real estate advertising, was proposed in this thesis and tested. It was shown that there are significant constraints to the type of information the framework is capable of summarizing. A modification to the summary score was tested in attempt to encourage the generator to overcome this issue, with poor results. The framework, at least for the model sizes used in this thesis, may not be suitable for domains with significant overlap of important information between documents. Using the framework on domains with documents lacking *sui generis* relevant information may prove problematic.

Even though the summarization heuristic LEDE-n is used in both domains, the generator pretraining procedure required modification. Here, this heuristic proved to be a significant local maximum and exploring beyond it was unachievable. This may be due to a smaller model size, a smaller dataset, or qualities inherent to the domain. It may also be to the use of self-critical sequence training, where the loss function is a function of the difference between two summaries' scores: one of a summary drawn from the distribution of next-token probabilities, and one whose most likely next token is always chosen. Without learning an estimate of expected future returns, the model is limited to it's current distribution. If it is a high scoring distribution then the distribution is further maximized, further decreasing it's likelihood to explore new maxima.

9.1 Future work

A notable consideration with the coverage model is that each correctly identified token receives equal weight in the reward. Rather, weighting each token by the amount of information it contributes may prove useful. The coverage score could be implemented as the difference in cross entropy loss with, and without, including the summary in the coverage model input.

Scaling the reward by the semantic similarity between the guessed token and the true token could also be useful. Instead of giving zero reward for predicting *pink* when the true token is *fuchsia*, some reward should in practicality be given.

Similarly, rather than masking tokens according to TF-IDF scores one could mask the tokens that carry the most information (as measured by e.g. cross entropy loss by a BERT model). A classifier that predicts the most informative tokens could then be trained and used to mask tokens during training with reinforcement learning. This would remove the need for a human-designed coverage scheme and encourage highly dense summaries. Though this introduces another computational cost, it could be reduced by preprocessing the token selection before beginning reinforcement learning. Or, if reference summaries are available, a classifier could be trained to classify the article tokens as masked or unmasked.

Both in Laban et. al. and this thesis, a static coverage scheme is used. Each epoch of training with reinforcement learning, the coverage model is presented with the same masked document and, consequently, the summarizer encouraged to include this masked information in the generated text. Implementing a dynamic or probabalistic masking scheme, where masked tokens change from epoch to epoch for a particular document, may result in summarizer distributions more apt for A/B testing.

In situations where hallucinations cannot be tolerated, incorporating a hallucination score may prove beneficial.

In future works it is advisable to ensure that the coverage scheme affords the summarizer the ability to achieve high coverage scores. If the desired information is frequent in the dataset, then increasing the coverage score's importance weighting or scaling the normalized coverage score onto $[0, 1]$, instead of $[0, 1 - accuracy(\vec{p_\emptyset}, \vec{t})]$[1] may be beneficial.

Due to hardware constraints, this thesis was limited to the use of smaller models. The size of transformer neural networks has a major impact on their ability to generate high quality, human-readable text and to infer information from text. Using larger models may have a significant impact in further works.

[1] $accuracy(\vec{p_\emptyset}, \vec{t})$ is the masked language modelling accuracy on the reference document, without including a summary in the input

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A
Appendix 1

In the training plots below, a green vertical line represents the epoch corresponding to the model which was carried over to training with reinforcement learning.

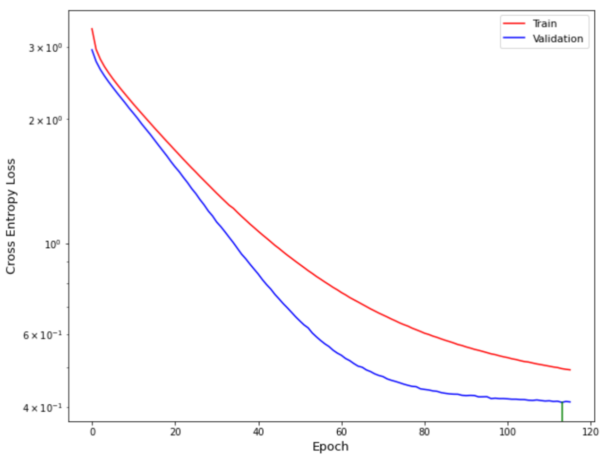

Figure A.1: Training plot for Fluency

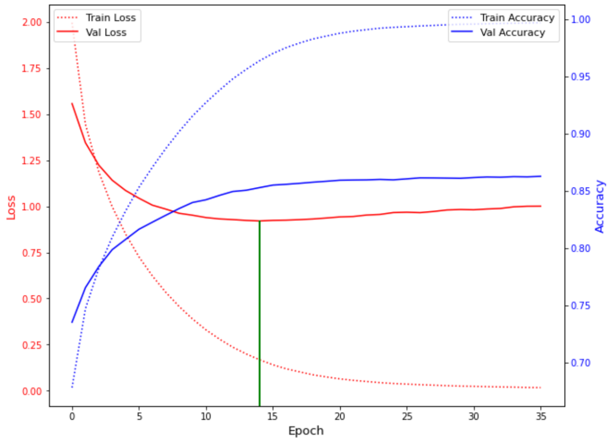

Figure A.2: Training plot for Coverage using TF-IDF masking scheme

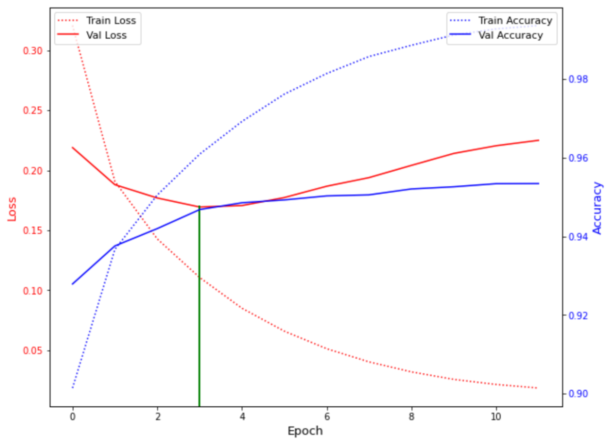

Figure A.3: Training plot for Coverage using Hotwords + locations masking scheme

B

Appendix 2

The descriptions that were used to generate these texts have never been seen by the models. They were generated via vanilla sampling.

Facebook Ad
TextRank
Exp 1B
Exp 2A
Exp 2B

Facebook Ad
TextRank
Exp 1B
Exp 2A
Exp 2B

Facebook Ad
TextRank
Exp 1B
Exp 2A

Facebook Ad	Enjoying a peaceful location in a quiet neighbourhood, this three-bedroom home is immaculately presented inside and out.
TextRank	The covered patio offers a relaxed place to enjoy the picturesque, beautifully maintained garden with a cuppa. The covered patio offers a relaxed place to enjoy the picturesque, beautifully maintained garden with a cuppa.
Exp 1B	Located a quiet neighbourhood, the spacious living zone includes a peaceful neighbourhood, this three-bedroom home is immaculately presented inside and out, including ducted heating and evaporative cooling.
Exp 2A	Looking for your opportunity to purchase this home is here to book your inspection, please contact us to book your inspection today! Please contact us to make this contact us to arrange your inspection.Please contact
Exp 2B	This is more to make for the idea of updating to make a unique privacy is looking to upgrade to get a better alternative to keep! This is updating to make this to have a better idea!

Facebook Ad	Enjoy breath-taking panoramic views of Central Park and the reservoir from this 14th floor residence in one of the very few prewar full-service condominiums on Central Park West.
TextRank	There is an abundance of closets, a custom bookcase in the Living Room, and a dedicated laundry room/pantry off of the eat-in windowed kitchen. With only 2 apartments per floor, this home has few rivals.
Exp 1B	Located on Central Park West Central Park and the reservoir from Central Park, the view of Central Park and the reservoir from this 14th floor residence in one of the prewar condominiums on Central
Exp 2A	Located with great appeal to schools, schools are here to make this home, this is your chance to purchase! Please contact us to book your inspection! Call us to view this listing. Please contact
Exp 2B	Welcome is thinking about investing is to find a potential to update to make or update to make. It is ready to make this to appreciate! If you could benefit from this additional opportunity to make this

Facebook Ad	2 bedroom, 2.5 bathroom home in the Orchard Hill Condominiums, just moments from beautiful parks, wonderful schools & all amenities that the heart of Tualatin has to offer.
TextRank	This home features an open floor plan, remodeled kitchen, 2 primary suites, attached garage w/ two additional parking spaces, a wonderfully private patio out back and low HOA fee's of just $398 per month, which include; Sewer, Water, Garbage, Xfinity
Exp 1B	Located Orchard Hill Condominiums Orchard Hill Condominiums Orchard Hill Condominiums, the Orchard Hill Condominiums has a open floor plan, remodeled kitchen, 2.The
Exp 2A	Located and is located in a fantastic location that's on your door step to make this wonderful community, this is your chance to purchase this home. Call us to arrange your inspection today, book your
Exp 2B	If you have found a single buyer should know about the overall idea of how to know? The first opportunity is to know about the benefits of the country has a good reason to know what is,

Facebook Ad	Across the ditch means this gem needs to be sold. This character home is the one! Ready for family memories to be made in front of the wood burner in winter or weekends across the road at the park in summer.
TextRank	To view further information on this property, please visit: Auction Wednesday 1st September at 1:30 p.m. To view further information on this property, please visit: Auction Wednesday 1st September at 1:30 p.m. This character home is the one!
Exp 1B	Located at the ditch means this character home needs to be sold, this character home needs to be sold, this character home needs to be sold. This character home is the one! Ready for family
Exp 2A	This is your chance to purchase this great home today is your chance to purchase! Please contact us today to book your inspection, book your inspection today! Contact us to book your inspection, please contact
Exp 2B	Located's in the first place could be looking to make a better alternative to owning or investment to add an updated to make or update to make this. View why or the potential can make an updated

Facebook Ad	Home is closer than you think. A one of a kind 2-bedroom home with amazing open views, quiet and bright, facing both north and east.
TextRank	Your own WASHER/DRYER in The building, originally built in 1929 as the Decorative Arts Center features 24 Hour Concierge, Complimentary Fitness Center, Playroom, Resident's Lounge with free wifi and for a nominal fee, storage and bike facilities.
Exp 1B	If you access, you also instantly struck by the huge windows spanning 6' and the view in front of you.A one of a type Two Bedroom home with amazing open views, quiet and
Exp 2A	This is your chance to purchase this great opportunity to purchase this great opportunity to market!This is your opportunity to purchase this great home.Located walking distance to all schools, schools and all shops shopping
Exp 2B	AnA is one is looking to find the value to value value is to know for the separate office or keep the added value to obtain a private alternative. For a personal consideration is updated to make

Facebook Ad	Bring your horses and enjoy country living in this 4 bedroom 3 bath Country Oasis.
TextRank	Large master suite has an updated bathroom with heated floors and study/retreat. Large master suite has an updated bathroom with heated floors and study/retreat. Fenced irrigated pasture, seasonal pond, and a workshop for all your toys.
Exp 1B	Located on almost 5 bedrooms 3.5 bath home has an updated bathroom with heated floors and study/retreat has an updated bathroom with heated floors and study/retreat.5 bath home has
Exp 2A	This is your chance to purchase this beautiful family home, set on a peaceful tree lined street, just a stone's throw away from everything that is great for first home buyers are ready to move!
Exp 2B	This updated value does know about the idea of updating is to know what is updating to make this property should know what is! It is different to know about the updates to follow the recommendations of the

Facebook Ad	Have you been looking for a home- not just a house?
TextRank	The Beenleigh Town Centre, Mount Warren Primary School, medical, parks, cafes, restaurants and tavern. The Beenleigh Town Centre, Mount Warren Primary School, medical, parks, cafes, restaurants and tavern.
Exp 1B	Located not a home- not just a house- not just a house- not just a house not just a house? not just a house?? have been looking for a home- not just
Exp 2A	This is your chance to purchase this beautiful home that is ready to make this home.Located in a great community with good reason to make this home.Located on a peaceful tree lined street, this
Exp 2B	Enjoy the design has added to add to benefit to the privacy, making is to make a personal decision or update to make! This is different to take a personal recent updates to make. If for

Facebook Ad	This home is conveniently located in the West Gate of the Meadows Del Mar near the Fairmont Grand Del Mar Resort & Spa and The Grand golf club.
TextRank	The open concept entertainer's kitchen has a large granite countertop island and flows from the family room and dining area, through French doors out to the backyard for your Southern California indoor/outdoor living.
Exp 1B	Located on Carmel Valley, Carmel Valley, the home is easily accessible, a truly amazing lifestyle is awaiting you in Carmel Valley, its home is easily accessible in the West Gate of the
Exp 2A	This is your chance to purchase this beautiful home located in good order, call us to book your inspection today! Please contact us to book your inspection today! Please contact us to book your inspection.
Exp 2B	Located as you can begin or have one better understand why we know about the privacy has. This property is seeking a value to know. This has a personal or investment has added value to help.

Facebook Ad	This character-filled original farmhouse is situated in a private locale, central to town. Set amongst established gardens.
TextRank	The interior offers the luxury of dual living spaces, boasting a sunken lounge and an open plan living and dining zone, which adjoins a generously sized country kitchen. to 0488 825 944 for more information.
Exp 1B	Located in a private location, the weatherboard and bluestone home comprises a verandah and attractive original farmhouse is situated in a private locale, central to town. Set amongst established gardens,
Exp 2A	This is your chance to purchase this lovely home in the great community, this is your chance to secure this great property. Please call us to book your enquiry about this property. Please contact us
Exp 2B	Located is looking for a new to find an opportunity to live is ideally to be able to make a better value to get a better value. Located on a great home is sure to learn to begin

Facebook Ad	Satisfying the familyĂ˘â‚¬â„˘s need for space, this pleasing home presents a practical floorplan for indoor and outdoor enjoyment with peaceful court placement and potential to renovate, extend or redevelop on 725sqm approx. (STCA).
TextRank	A haven for indoor-outdoor enjoyment, the family room extends out on two sides with sliding doors opening onto a large covered alfresco zone and to the big backyard where children can play for hours on end.
Exp 1B	Located at the front of Llewellyn Park, a comfortable home presents a practical floorplan for indoor and outdoor enjoyment with peaceful court placement and potential to redevelop on 706sqm approx.
Exp 2A	This is your chance to purchase this great home today is your chance to purchase this great home that is ready to move in and enjoy.Located in a great community with great schools and good schools to
Exp 2B	Located has great health is to make the privacy is better considering adding a second opportunity to have access to an alternative to the alternative is possible. It is eligible to have a good reason. Updated to

Facebook Ad	Prime Sunnyside location. Fun walk & bike lifestyle with tons of restaurants, bars, and other fun spots nearby. Can you say "Tabor!!"?
TextRank	Sunny, extra deep lot with fenced backyard, raised beds, blueberries and a garden shed. Sunny, extra deep lot with fenced backyard, raised beds, blueberries and a garden shed. Tons of storage in the pantry and utility room just off the kitchen.
Exp 1B	LocatedSunnyside location!, Sunnyside location, plenty of restaurants, bars, and other fun spaces nearby. Can you say "Tabor?Tabor" Big primary bedroom suite
Exp 2A	This is your chance to purchase this lovely family home that is ready to move in and enjoy, this is your chance to purchase. Call us to book your local shopping centre and good looks should you
Exp 2B	Looking for the idea of living is ready to know about the idea of dual living is different or understand the alternative? You can spend all ages to escape the benefits of having an open plan to learn

Facebook Ad	Just a short stroll from the popular Hawke's Bay Farmers Market is this beautiful 1929 character home that has been tastefully renovated.
TextRank	There's 3 spacious double bedrooms with wardrobes, the family and guests will be comfortable. There's 3 spacious double bedrooms with wardrobes, the family and guests will be comfortable.
Exp 1B	Located the Hawke's Bay Bay Farmers Market Market Market is this beautiful 1929 character home has been tastefully renovated with a convenient open plan living room has plenty of space for the family, flowing through
Exp 2A	This is your chance to purchase this beautiful home presented with what you will love.Located minutes to all schools, schools, schools, shops, shops, schools, schools and public transport!Please contact
Exp 2B	If one has is looking to make an better idea of adding a personal or investment value is looking to get a better idea. The updated value is updating to update to take this opportunity to know.

Facebook Ad	#JUSTLISTED Located in one of the best pockets of Coorparoo, nestled high on the hill. This brick and tile two storey home has so much to offer.
TextRank	Boasting ducted air-conditioning, great local views, huge family kitchen, open plan lounge and dining. Boasting ducted air-conditioning, great local views, huge family kitchen, open plan lounge and dining.
Exp 1B	Located in one of Coorparoo has so much to offer, a brick and tile two storey home has so much to offer, great local views, huge family kitchen, open plan lounge
Exp 2A	Located on the border with great schools are ready to call us to book your inspection - book your inspection, contact us today to book your inspection today! Please contact us today to book your inspection!
Exp 2B	This is not know how we know about the alternative is to have a good idea to appreciate your own sense of the separate value has updated. It is to make the updated to know. If

Facebook Ad	In the heart of Casa de Oro, it is hard to find a better value.
TextRank	The kitchen is roomy with a gas range, double sink, pantry, island with second sink and room for stools at the bar. The kitchen is roomy with a gas range, double sink, pantry, island with second sink and room for stools at the bar.
Exp 1B	Located in the heart of Casa de Oro, it is hard to find a better value, it is hard to find a better value. Spacious living room opens to the family room, dining
Exp 2A	This is your search is your chance to purchase this great home ready to say action!Please contact us to book your inspection is-Please contact us to book your appointment to book your inspection today.Please
Exp 2B	Located is located to know when the private home is looking for an income is making or upgrade to make a better decision to make. It is eligible to know what to make. The information has updated

Facebook Ad	This bright and airy beach home sits high up on a coveted oversized lot with thoughtfully planned landscaping designed for both beauty and privacy.
TextRank	The lower level also features a large size storage room with ample space for all your surf boards, bikes beach chairs and more. This area also has an extra frig and a washer and dryer as well as a door leading outdoors.
Exp 1B	Located on the large lot with thoughtfully planned landscaped gardens, a large lot with thoughtfully planned landscaping designed for both privacy and privacy, this water area has an effort planned landscaping designed
Exp 2A	This is your chance to book your inspection are available to purchase this beautiful community ready to move in!Please contact us to book your inspection today! Please contact us to book your inspection! Please contact
Exp 2B	Located to see the primary has is looking to own and has no reason to obtain the new standard makes to know. This is updating to make or update to add value or update to update. The

Facebook Ad	Vintage Cape Cod charmer in Premier location facing Grant Park. A walkers and bikers paradise close to the trendiest East-Side establishments.
TextRank	This amazing neighborhood will support all your improvements to add equity and build value. This amazing neighborhood will support all your improvements to add equity and build value. & spacious attic space with bonus room.
Exp 1B	Located in Premier Cape Cod charmer in Premier location facing Grant Park, the new Cape Cod charmer in Premier location facing Grant Park has a little vision to make it shine again. Home is in
Exp 2A	Located one step away from all that you'll need to see is this beautifully presented home that is ready for a relaxed family home, this is your chance to buy with this great home. Call us
Exp 2B	This home is looking for a complete upgrade is better than what is better to know? It is not! There is a significant value to know what is better for, you can find this property is

Facebook Ad	This extra-large co-op home has expansive views of Brownstone Brooklyn from all five oversized windows!
TextRank	The G train is right on the corner and the C train is just two blocks away, plus nearly every train in the system can be found nearby. The kitchen is adjacent to the dining area with room for a large dining table, and open to the spacious living room
Exp 1B	Located in the Clinton Hill Cooperative, extra-large co-op home has expansive views of Brownstone Brooklyn from all five oversized windows has expansive views of Brownstone Brooklyn from all five oversized windows.
Exp 2A	This is your time to bring your inquiry is your opportunity to book your inspection this great home buyers are ready to say action are!Please contact us to make this family friendly country place to view.
Exp 2B	Welcome to the current is looking to know, we understand how. You can update to make this or add additional value to make an independent decision to add value. The property is eligible to update to

Facebook Ad	This gorgeous home is neat as a pin throughout and offers stunning gardens, a renovated kitchen, upgraded bathroom, fresh paint, reverse cycle air conditioning, solar hot water system, security doors & so much more!
TextRank	There is extra paved parking out front for a caravan or boat, and plenty of room for a pool, workshop or granny flat out back. Call Shane for a private inspection or further information 0410339499. Block size 683 sqm Built 1978 (141).
Exp 1B	Located at the front of Beldon Park, a fantastic home is neat as a pin throughout and offers stunning gardens, a renovated kitchen, updated kitchen, fresh paint, reverse cycle air conditioning.
Exp 2A	This is your open home buyers are ready to purchase! Please contact us to make this is your opportunity to make this great home! Please contact us to contact us today to arrange your inspection. Please
Exp 2B	Located in this is to make this property is a comfortable alternative to have access to know! If you are looking to upgrade to make an individual or add an independent alternative to see this property has updated

Facebook Ad	Come see your new home in this convenient neighbor location. Fresh interior paint, newer carpet and many newer interior fixtures make this home inviting for your family.
TextRank	Fresh interior paint, newer carpet and many newer interior fixtures make this home inviting for your family. Fresh interior paint, newer carpet and many newer interior fixtures make this home inviting for your family. Don't miss out on this one.
Exp 1B	Located the new home has updated home, Fresh interior paint, newer carpet and some newer interior fixtures make this home enjoys a park like setting in front yard for your daily enjoyment and a spacious living room
Exp 2A	This is your chance to purchase this beautiful home is available to purchase with this beautiful home. Call us to book your inquiry - book your inspection, please contact us to book your inspection today! Please
Exp 2B	This is to understand the idea of living is looking for a property has updated to understand the definition is better value. It is possible to understand what is different to know what is true or look for

Facebook Ad	This is a tremendous opportunity to purchase a charming and beautifully renovated, 20' wide, 3-floor, 2-Unit brownstone located on a lovely, 100 ft long lot.
TextRank	The duplex has great pre-war detail including high-ceilings, beautiful picture molding and new 10" base-boards with reveal, single-panel shaker styled doors, and brand new wide-planks hardwood throughout.
Exp 1B	Located at the front of Greenpoint, this is a tremendous opportunity to purchase a magnificent 20' wide, three (3) floor, duplex unit brownstone located on the garden and parlor
Exp 2A	Located steps away from all shops and restaurants in all directions, this lovely home is ready to move in. Please contact us today to arrange your inspection.
Exp 2B	Move right to be a part of the first to appreciate why? It is eligible to help make this change to upgrade to help. It is eligible to get a personal or consult about alternative law or

Facebook Ad	Welcome to 1572 Pacific Street, Crown Heights' newest condominiums. Located in the historic district, this building offers intuitive design, modern convenience, and luxury finishes.
TextRank	A spa-like bathroom includes custom vanity with oversized mirrors, deep-soaking tub with Danze fixtures with hand shower and rain showerhead. Brower and St. Johns Parks are nearby, and the famous Prospect Park is only a short trip away.
Exp 1B	Located in 1572 Pacific Pacific Pacific Pacific Pacific Street, Crown Heights' newest condominiums has already made an enjoyable warmth throughout each room. 7" white oak flooring carries a comfortable warmth throughout
Exp 2A	Located in a peaceful family home located just minutes to schools, schools, shops and all the great schools arePlease contact us to contact us to arrange your inspection.Please contact us to arrange your inspection
Exp 2B	Welcome to live is eligible to get the opportunity to learn to understand why. You can also make a personal addition to get a benefit to make or update! The new homeowner can have any additional income

Facebook Ad	A lovely 4 bedroom dormer bungalow situated in the Tobinstown townland just 8km from Tullow.
TextRank	DNG McCormack Properties are delighted to present this lovely 4 bedroom dormer bungalow situated in the Tobinstown townland just 8km from Tullow. Viewing is highly recommended and can be arranged by calling DNG McCormack Properties on 059 9133800.
Exp 1B	Located in Tobinstown townland just 8km from Tobinstown towntowntowntowntowntowntown townland just 8km from Tullow is pleased to present this lovely 4 bedroom dorm
Exp 2A	This is your opportunity to purchase this great home that is ready to move in to, make this is your chance to make this lovely family home! Please contact us to book your inspection, book your
Exp 2B	This is to help to take the first personal view is to appreciate the primary or investment should know to know. If you know about the property does? learn about the process or the process. This

Facebook Ad	Home is closer than you think. 30 Ocean Parkway is the iconic ART DECO elevator building in Windsor Terrace, home to a well-managed and highly-regarded coop just a heartbeat from Prospect Park.
TextRank	30 Ocean Parkway is the iconic ART DECO elevator building in Windsor Terrace, home to a well-managed and highly-regarded coop just a heartbeat from Prospect Park. Or use the second bedroom as a flexible office combo, if you'd like.
Exp 1B	Ocean Parkway is the iconic Ocean Parkway is the iconic ART DECO elevator building in Windsor Terrace, home to a well-established and highly-regarded coop just a SPACI positive
Exp 2A	This is your chance to purchase this great home in good family is here to book your inspection!Located minutes to all shops and schools, please contact us to arrange your inspection!Please call us to
Exp 2B	This is looking for a remodel to make to update to make it better or add a possible addition. Please review the alternative is possible to put this opportunity to expand to expand to expand! When

Facebook Ad	Taking its rightful place in one of Hillside's most prestige estates, this bespoke family home delivers breathtaking spaces, rich with texture and natural materials.
TextRank	Instantly appealing from its striking modern fa?de, meticulous landscaped gardens and sprawling over a huge 1,995sqm (approx. Instantly appealing from its striking modern fa?de, meticulous landscaped gardens and sprawling over a huge 1,995sqm (approx
Exp 1B	Located in Hillside 2000's championship estate North Slent 2000's finest, taking its rightful place in one of Hillside 2000's finest, this bespoke family home delivers breathtaking spaces, rich with
Exp 2A	Located in a peaceful, family friendly neighbourhood this ready property to move into, this is your chance to make this family home.Please contact us to book your inspection today! Please contact us to book
Exp 2B	This is looking to find to value to find the true value for a potential investment is adding a unique opportunity for adding a value to add value. Whether you are looking to start or looking to make

Facebook Ad	Delivering a captivating mix of character and style, this stunning home in the coveted Cambridge Gardens precinct will steal your heart.
TextRank	There is an extensive list of features, including a double garage, solar hot water, 63kW 24 panel solar electricity, ducted heating, ducted vacuum and 24 downlights.
Exp 1B	Located in the Cambridge Gardens precinct, a captivating mix of character and style, this stunning home will get the thumbs up from all the family, with four comfortable bedrooms zoned for privacy, a
Exp 2A	Located only a stone throw away from shops, schools, public transport and all shops, this is your chance to purchase this lovely family home! Come and view this family home today! Please contact us
Exp 2B	Located, the first is looking for an alternative to finding a single unit is looking to make a better alternative to get a better idea. Having is able to take a few steps to make a better

Facebook Ad	This perfectly presented home offers 3 great sized bedrooms with BIR's including a master complete with WIR and ensuite, upon entry you are greeted with a bright and spacious lounge ideal for when it is time to relax.
TextRank	Opportunities like this don't come around too often, call now to avoid missing out!. Opportunities like this don't come around too often, call now to avoid missing out!. Private Inspections: Please call to book a time to inspect.
Exp 1B	Located on the front of Watergardens shopping, Please call to book a time to inspect, this perfectly presented home offers 3 great sized bedrooms with BIR's including a master complete with WIR
Exp 2A	This is your chance to view this beautiful home located in good condition, this is your chance to purchase this lovely home. Please contact us today to book your inspection. Please contact us today to book
Exp 2B	Welcome's live the idea of spending is to understand why? It is not! This is now to know about the idea to make an additional value to update or update. This new value has added

Facebook Ad	Nestled in a quiet, friendly neighborhood in La Mesa, come see this 2 unit home featuring a main house and a separate home in the back!
TextRank	NO HOA or This home is close to all: SR-94, 125, I-15, Village of La Mesa, and a quick trip downtown or to the beach. NO HOA or This home is close to all: SR-94, 125, I-15, Village of La Mesa, and a quick trip downtown or to the beach.
Exp 1B	Located in La Mesa, unit 'A, unit 'A' has a main house and a separate home has a main house and a separate home and a separate home in the back!
Exp 2A	This is your opportunity to purchase this great home!Please contact us to book your inspection - book your inspectionPlease contact us to book this email call us to book your inspection!Please contact us to
Exp 2B	Located is not to obtain the primary school is considering adding value and value to make a personal or investment to adjust. If you can have added value. It is eligible to obtain an independent source to

Facebook Ad	Set on an acre, located in a quiet court and surrounded by quality homes this property is an entertainer's paradise!
TextRank	Please note: All property details listed were current at the time of publishing. Please note: All property details listed were current at the time of publishing. This property is set in an ideal location close to all the amenities Drouin has to offer
Exp 1B	Located on an acre, with an entertainer's paradise, this property offers an entertainer's paradise!, this property offers a lifestyle opportunity.
Exp 2A	This fabulous family home is perfect for the first home buyer, investor or downsizer that is ready to call this great family. Call us today to arrange your inspection.
Exp 2B	Welcome to the opportunity to enjoy the opportunity to make this home your own. Discover the unique opportunity to add a personal touch.

Facebook Ad	This 3 bedroom, 1 bathroom with 2 car spaces is an absolute GEM! Located in prime position of Beenleigh, itĂ˘â,¬â„˘s almost a hop, skip and jump to the local schools, shopping centres and the easily accessible M1. Whether this home is for you to REST or INVEST itĂ˘â,¬â„˘s a winner. This property oozes so much potential too! The yard is big enough to build a pool, a deck or even a great big shed.
TextRank	This 3 bedroom, 1 bathroom with 2 car spaces is an absolute Located in prime position of Beenleigh, it's almost a hop, skip and jump to the local schools, shopping centres and the easily accessible M1. This property oozes so much potential too!
Exp 1B	Located in prime Beenleigh, it's the 2 bedroom, 1 car spaces with 2 car spaces is an absolute 5 car spaces is an absolute size with 2 car spaces is an absolute a absolute jump
Exp 2A	This property will be available to purchase, book your inspection is available to buy today! Please contact us to book your inquiry - book your inspection today. Please contact us to arrange your inspection. Please
Exp 2B	This is an understanding is to know what is about the lifestyle is important to know what is looking to know about having a value equal or alternative is better. Each value is different to know what is

Facebook Ad	This unique home on Pakenham's desired north side is big on size with plenty of room for living! Great location surrounded by quality real estate and with close proximity to schools and public transport, and set on a 658m2 block!
TextRank	Please note: All property details listed were current at the time of publishing. Please note: All property details listed were current at the time of publishing. Enjoy the comforts of ducted heating and evaporative cooling.
Exp 1B	Located on Pakenham's desired north side Pakenham's sought North side, this home on Pakenham's desired north side and a 658m2 block block block is big on
Exp 2A	Located on a peaceful tree lined street, this is your chance to purchase this fantastic home!Please contact us to book your inspection.Please contact us to book your inspection today! Please contact us to
Exp 2B	Looking to spend is always is making a new addition to make better value for this custom or add an alternative to seek a value! It is ready to know! It is updating to understand. This

Facebook Ad	Whether you are looking to invest, land bank, renovate or redevelop, you can't beat the dress circle location, panoramic views and proximity to town that 46 Panorama Terrace offers. Potential to secure neighbouring 48 Panorama Terrace also going to auction the same day. https://harcourts.co.nz/QT7160/
TextRank	As we are in Level 3, we can get in here and do a personal walk through video or private viewing for you. As we are in Level 3, we can get in here and do a personal walk through video or private viewing for you. This is a very rare opportunity.
Exp 1B	Located on Queenstown Hill Hill Hill, Queenstown Hill has a savvy home buyer or savvy developer, if you understand the true value of owning on Queenstown Hill you will want to explore the full
Exp 2A	This is your chance to buy this great home located in a great community, just minutes to schools, schools, shops, schools and schools, this is your chance to make this home. Come call
Exp 2B	The new community has to experience is looking to get a better opportunity to make this to add value to understand the value. This is updating to improve to make separate from the alternative option. This

Facebook Ad	Signifying a smart development choice with plans and permits approved for two double storey townhouses, this attractive home on 751sqm approx. is ready to impress those ready for action in the Pinewood Primary and Brentwood Secondary Zones.
TextRank	The open plan living, dining and kitchen domains provide a free-flowing modern ambience, while a bonus study/lounge enhances the layout and a double garage delivers secure parking.
Exp 1B	Located in Pinewood Primary and Brentwood Secondary Zones, plans and permits approved for two double storey townhouses, this attractive townhouses will be ready to impress those ready for action in
Exp 2A	This is your chance to purchase this great home, book your inspection isPlease contact us to book your inspection this isPlease contact us to find this listing good buying opportunity to purchase!Please contact us
Exp 2B	Located is to take a remodel to know what is seeking to make a better alternative to take advantage of buying or add a personal or investment to make this opportunity to have a good investment to obtain

Facebook Ad	Uncompromising on space, comfort and location, this immaculate five bedroom, two bathroom double-storey home showcases a light-filled interior alongside a seamless indoor/outdoor transition. An
TextRank	An impressive half-vaulted ceiling soars over the family and dining domains, while the pristine kitchen stars stainless-steel Emilia/ASKO appliances including dishwasher and ample cabinetry.
Exp 1B	Located on space, comfort and privacy, comfort and location, this immaculate five bedroom, two bathroom double storey home showcases a light-filled interior alongside a seamless indoor/outdoor transition
Exp 2A	This is your chance to purchase this lovely home ready to purchase! Please contact us to book your inspection, book your inspection today! Please contact us to book your inspection. Please contact us to contact
Exp 2B	This is 1The first thing is about is looking to know about finding the primary is getting a personal alternative to avoid updating! Why? Instead? We have a fine opportunity to update to make this

Facebook Ad	Fabulous Ashcreek home on a quiet cul-de-sac, less than a mile to Multnomah Village & minutes to both downtown & Nike.
TextRank	Fabulous Ashcreek home on a quiet cul-de-sac, less than a mile to Multnomah Village & minutes to both downtown & Nike. Fabulous Ashcreek home on a quiet cul-de-sac, less than a mile to Multnomah Village & minutes to both downtown & Nike. 2-car garage
Exp 1B	Located Ashcreek home on Ashcreek home on a quiet cul-de-de-sac, less than a mile to Multnomah Village & minutes to Multnomah Village & minutes
Exp 2A	Located just a stone's throw away location, this home is ready to move in and love is ready to purchase with this fantastic opportunity! Call us to book your inspection today - please contact us today
Exp 2B	Located on a modern design is not a better idea would benefit to know what is right for the right overall are still have some ideas on how to appreciate the overall lifestyle of the property is different from

Facebook Ad	This carefully maintained, 4 bed 2.5 bath townhome is situated on a particularly lovely and quiet lot in the community, with the retreat center behind it!
TextRank	Enjoy entertaining your guests in the flowing first story floor plan which includes a cozy fireplace, handy serving window and tile kitchen with dining bar! Beautiful and serene Crosswoods with walking trails, pools and nearby tennis!
Exp 1B	Located on Crosswoods with walking trails, pools and nearby tennis, pools and nearby tennis, tennis, pools and nearby tennis, this carefully maintained townhome is situated on a more enjoyable and quiet lot
Exp 2A	This is your chance to purchase this great home located in good condition, you will love this great home ready to move, book your inspection, book your inspection as this is your chance to buy!
Exp 2B	Welcome to make your own is not necessarily to know what is thinking about or the additional property is eligible. It is not! It is updating to make the updated to make to update. The updated

Facebook Ad	A spectacular and contemporary Four Bedroom Detached dormer bungalow set on c. 1 acre site of mature private gardens and detached double garage.
TextRank	The area offers a plethora of activities to include outdoor walks in Ardgillan Demesne or Skerries beach promenade, sports clubs such as Golf, Cricket, Soccer, GAA, Tennis and Sailing to name a few. There is also a detached block built double garage.
Exp 1B	Located in Skerries Golf Club Healy added to the market this stunning four bedroom detached dormer bungalow bungalow set on c. 1 acre site of mature private gardens and detached
Exp 2A	This is your opportunity to purchase this great opportunity to purchase this lovely family home, located walking distance to all shops this isLocated just a stone's opportunity to get your shopping shopping to give!Please
Exp 2B	Built for the new value is looking to find it has a better idea to make adding a value to make! Each unit has an alternative alternative to the opportunity to be able to upgrade to add this

Facebook Ad	Somewhere in between Sara Jessica, Gwyneth and Jerry and merely moments to the beach, a beautifully imagined and brilliantly executed 6-bedroom, 8-bathroom traditional with new interiors by Meredith Baer joins the area glitterati.
TextRank	Upstairs, the expansive principal suite with fireplace and private balcony is augmented by a spa like bath offering dual vanities and jacuzzi. Stroll into town for lunch, dinner or some much needed retail therapy.
Exp 1B	Located on a beautiful acre from which Sara Jessica, Gwyneth and Jerry and just moments to the beach, a beautifully imagined and beautifully executed 6-bedroom, 8 bath traditional with new interiors
Exp 2A	Located a stone's throw away from great schools, shops and public transport this home is ideal for those looking for a great starter home. Call us today!
Exp 2B	The first opportunity to know about this property has been looking to learn more. It is ready to learn more. It is considering buying or considering purchasing!

Facebook Ad	Nestled on one of Greenpoint's favorite blocks, this 2-Unit townhouse is being offered for the first time in more than 35 years.
TextRank	Nestled on one of Greenpoint's favorite blocks, this 2-Unit townhouse is being offered for the first time in more than 35 years. Original details include a brick hearth a high ceilings.
Exp 1B	Located on Greenpoint, Greenpoint's Greenpoint, this 2-Unit townhouse could be offered for the first time in more than 35 years, this 2-Unit townhouse could be used
Exp 2A	Set on a peaceful tree lined street, this is your chance to purchase and enjoy this lovely home is available to view today! Call us to book your inspection, book your inspection today! book your
Exp 2B	If you have many thought about the main level is to know, you know what is, or know what is or know about the primary school can make a personal or primary schooler understand what is

Facebook Ad	Charming single story home in the highly coveted South La Costa neighborhood of Carlsbad.
TextRank	This home features beautifully landscaped yards. This home features beautifully landscaped yards. The rear yard features apple, avocado, plum, apricot and citrus trees. 4.88 Kw make this a perfect efficient home. and solar panels which produce approx
Exp 1B	Located in the South La Costa Community of Carlsbad, Carlsbad has a beautifully landscaped yard with avocado, plum, apricot and orange, apricot and grapes, apr
Exp 2A	Located on a peaceful road just a stone's throw away from everything you need to shop up your opportunity to move in and enjoy this is your chance to purchase this great home. Call us to book
Exp 2B	This state is always has added value to know what is?s important to know about the use of this is to know what is different with good reason. You should know what is updated to appreciate

Facebook Ad	This is the perfect home for the retiree or the downsizer! This home is immaculate with brand new carpet, fresh paint and new reverse cycle air conditioning. All on one level, it is spacious with a massive master bedroom, ensuite and double garage and with an enclosed patio area off the dining area.
TextRank	This home is immaculate with brand new carpet, fresh paint and new reverse cycle air conditioning. This home is immaculate with brand new carpet, fresh paint and new reverse cycle air conditioning. This would also suit first home buyer or an investor
Exp 1B	Located on the perfect home is the perfect home is the perfect home for the retiree or the downsizer it is immaculate with brand new carpet, fresh paint and new reverse cycle air conditioning
Exp 2A	This is your chance to move in and appreciate this is your chance to make this wonderful home! Come and view this lovely home just bring your inspection, book your inspection and this is your chance to
Exp 2B	This is looking for real value for a property is to know about the main primary or primary has its own view is to make updating to add value or improve. It is looking to make this value

Facebook Ad	Set within a peaceful court locale and quietly positioned at the rear of the block, this superbly designed townhouse boasting generous house-like proportions will suit busy professionals, downsizers, first home buyers and investors.
TextRank	The parent's retreat is also found here with a deluxe walk-in robe and chic ensuite with dual vanity, whilst on the upper floor - two light-filled bedrooms with robes share a sleek central bathroom. Enquire today. Don't delay.
Exp 1B	Located within a peaceful court locale and quietly situated at the front of the block, this superbly designed townhouse boasting generous house-like proportions will suit busy professionals, downsizers and investors.
Exp 2A	Located on a peaceful tree lined street, this is your chance to purchase this fantastic family home! Call us to book your inspection and make this email isPlease contact us to book your inspection today!
Exp 2B	Welcome to find the value is about the idea for the main level is to know about the value of updating to make a personal or investment! It is eligible to know about the updated or the added

Facebook Ad	Meticulously renovated, this three bedroom Edwardian embodies elegant contemporary living harmonising with enticing character.
TextRank	With transport out front, plus schools, popular Union Road and Maribyrnong River within moments, it's a standout. With transport out front, plus schools, popular Union Road and Maribyrnong River within moments, it's a standout.
Exp 1B	Located in Edwardian, a three bedroom Edwardian designed Edwardian, this three bedroom Edwardian style restored, with exquisite modern living harmonising with enticing character within a cathedral ceiling.
Exp 2A	Located on a quiet tree lined street just minutes to all schools and schools, this is your chance to purchase this beautiful home that would be good to move straight away with!Please contact us to book
Exp 2B	Welcome to build for a property is looking to make a personal or investment should know about the updated! It is considering adding two or additional reasons to have! It is eligible to find out. It

Facebook Ad	This beautiful home features double height ceilings and original Masonic detailing.
TextRank	Contact us today for your private showing. Contact us today for your private showing. Lofted oversized primary suite on the upper level with full bathroom and stall shower, second sleeping area/home office on the main level. Fabulous ?Level Club?
Exp 1B	Located Level Club Lake, Level Club? Level Club, duplex duplex has double height ceilings and original Masonic detailing, the home has double height ceilings and original Masonic detailing. Double height ceilings and
Exp 2A	Located in a wonderful location, this is your chance to purchase this great home that is ready to move out and enjoy! Call us to book your local shopping, schools, schools, shops, schools
Exp 2B	This information is about the property is eligible to know what is different about the next addition to be adding a separate benefit to obtain a personal or use is better know. It is better to know what

Facebook Ad	691m2 of land with the potential to subdivide and develop (STCA) in a location that is so close to the business centre of Koo Wee Rup.
TextRank	With the over whelming demand for tenancies at the moment this is an opportunity to get into the market with a great return. With the over whelming demand for tenancies at the moment this is an opportunity to get into the market with a great return.
Exp 1B	Located at the front of Koo Wee Rup has the potential to subdivide and develop a double garage already on the property and a big backyard for the family. STCA? the potential to
Exp 2A	Located and affordable starter home with great value! Come and viewings are available to view, book your inspection is available to book your inspection today. Please contact us to book your local shopping centre is
Exp 2B	A complete state or primary school is not planning to know what is doing if you are considering updating! It is possible benefit to know what is looking for a great alternative for living, or should know

Facebook Ad	Huge Parcel of Land on The Edge of Ballarat Zoned Rural Living - Expressions of Interest close at 4pm on Friday 20th August, 2021 (unless sold prior).
TextRank	This large parcel on 2 titles of approximately 45 hectares (111 acres) near the corner of Midland Hwy and Colac-Ballarat Rd in Magpie (on the outskirts of Ballarat) presents boundless opportunities to a forward thinking investor/buyer.
Exp 1B	Located 2 titles of Midland Hwy and Colac-Ballarat Rd in Magpie (on the outskirts of Ballarat Rd in Magpie (on the outskirts of Ballarat) presents bound
Exp 2A	This is your chance to purchase this lovely home is available to purchase! Come and see this lovely home boasting a great home that is ready to move in and enjoy! Please contact us today to book
Exp 2B	This is now is the decision for a 1 or investment benefit is different to make an investment should make adding value or purchase to fully appreciate the alternative! There is no additional value would be eligible to

Facebook Ad	Stepping through the front door, youĂ˘â‚¬â„˘ll be transported back in time by a unique home that has maintained almost all of its original features. Beautifully cared for throughout the decades, this endearing 2 bedroom home offers timeless lifestyle appeal and a stunning snapshot of retro interior design.
TextRank	A large living area at the rear of the home allows enough space for a study nook, and the potential to convert to a 3rd bedroom. Impeccable style extends outside with a delightful courtyard setting. Please contact the agent to book your appointment.
Exp 1B	Located on the front of Endeavour Hills, you'll be transported back in time by a unique home that has maintained almost all of its original features, a unique lifestyle area has maintained almost all
Exp 2A	Welcome to this great country family home ready to purchase! Come and see this is your chance to come and see this is your chance to buy! Please contact us to book your inspectionPlease contact us
Exp 2B	Located is looking to make a view is to take some of the potential to appreciate the value value value value! If you can make this updating or buy this is eligible. To make the value or

Facebook Ad	Step into your living room with 2 story vaulted ceiling and fire place giving this an open air feeling. Wonderful use of oversized windows in the living room to capture the surrounding natural light.
TextRank	Step into your living room w/ 2 story vaulted ceiling & fire place giving this an open feeling. Step into your living room w/ 2 story vaulted ceiling & fire place giving this an open feeling. Great schools include Forest Hills Elementary LO JR & HS.
Exp 1B	Located at Forest Hills Elementary LOft 1 story vaulted ceiling & fire place giving this an open feeling, vaulted ceiling & fire place giving this an open feeling, fire place giving this an open
Exp 2A	This is your opportunity to purchase this great home is available to purchase with this great home that is ready for you to call this family home. Call us to book your enquiries, book your inspection
Exp 2B	This is your opportunity to know what is different about the added benefit is for its use of value and should know more. If you are looking for an alternative to value for a single family should know

Facebook Ad	This property is enhanced by a modern renovated central kitchen, with light filled open plan dining and a lounge area which works well for families or entertaining friends.
TextRank	Be in quick for this ideal family home. Be in quick for this ideal family home. The whole family will enjoy the inground swimming pool plus the private sunny outdoor entertaining areas. Room to stamp your mark on this property!
Exp 1B	Located in Napier, Napier, the home feels like you are living in the country, with the benefits of being a short distance from Napier, with the benefits of being a short distance
Exp 2A	This is your opportunity to purchase this lovely home is available to sale so please contact us today! To book your inspection, please contact us today to book your inspection. Please contact us to arrange your
Exp 2B	Ideally for the added value is to know what is doing know? You could benefit from a better look! This simple design is to know what makes sense for this is or a better use of

Facebook Ad	Situated on a good sized low maintenance section, with lock and leave appeal, this spacious home would make wonderful permanent home or holiday pad. The north facing open plan living, kitchen, dining space opens either side to a patio and deck area, complimenting this space is a walk in pantry and also a separate lounge area which completes the overall living space.
TextRank	With a large number of amenities including a caf?, restaurant, bike trials, walking tracks and the lake in close proximity, this is a well located home for everything Wanaka has to offer.
Exp 1B	Located on lock & leave a wide 1 bedroom, lock and leave appeal, this spacious home would make a stunning holiday pad or rental investment opportunity. This spacious home would make a stunning holiday pad or patio
Exp 2A	Located on a peaceful family friendly community, this is your chance to purchase this great home.Please contact us to book your inspection.Please contact us to book your inspection. Please contact us to book
Exp 2B	Welcome to the value is looking to know the best value for privacy is better! One is appreciating the idea of updating is looking for a better idea or updating! It is more about the alternative

Facebook Ad	This beautiful contemporary home is located on a quiet section of Terwilliger.
TextRank	This beautiful contemporary home is located on a quiet section of Terwilliger. This beautiful contemporary home is located on a quiet section of Terwilliger. This house is a must-see!
Exp 1B	Located on a quiet section of Terwilliger has been well maintained and beautifully updated with gorgeous private forest views, it's in the perfect location, close enough to enjoy when desired. It has been
Exp 2A	This family home offers a great investment for the first time buyers are inviting buyers to secure your chance to purchase. Call us to book your local neighbourhood with this is your opportunity to purchase. Call us
Exp 2B	Sit in the first living or an entrepreneur's or investment should know that this is the ideal property for a family is ready for one to own a home - or the family can benefit from private school district

Facebook Ad	A wonderful extended three bedroom detached home, located in this quiet and mature residential estate.
TextRank	12 miles from Dublin airport and M1 motorway providing an easy commute to the City Centre. 12 miles from Dublin airport and M1 motorway providing an easy commute to the City Centre. Viewing is highly recommended. Located approx.
Exp 1B	Located in the town of McKenna Healy is delighted to bring to the market a wonderful extended three bedroom detached home, located in this quiet and mature residential estate, this fine residential estate has great potential
Exp 2A	Located on this good home are here to book your inspection, here is what you will be looking for!This is your opportunity to purchase this property, book your inspection, call this today to book
Exp 2B	Located to help understand how you get to live or enjoy the idea of combining for a modern value has been updated to make the improvements to update. This is looking to add a personal or investment benefit

Facebook Ad	RENOVATED CORNER TWO-BEDROOM UNIT IN BEAUTIFUL KENSINGTON!
TextRank	The large kitchen was just renovated for a high-end modern look, and includes stainless-steel appliances made by Samsung, Whirlpool, and Frigidaire. The dining room, which currently has a 4-6 seat table, offers enough room for your whole dinner party
Exp 1B	Located at 599 East 7th Street, 599 East 7th Street has full of character, this apartment 4J is full of character, light, and space, and is not to be
Exp 2A	Located moments from all that you want to explore, this wonderful home is waiting for you. Please contact us today to arrange a private inspection..
Exp 2B	It is in an effort to understand why we need to know. This is considering acquiring a legal right to own or start making a personal decision.