BERT-based language models for US Elections, COVID-19, and analysis of the translations of the Bhagavad Gita

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Overview

- Language modelling with deep learning
- Language models for Twitter sentiment analysis leading to the US 2020 presidential elections.
- Sentiment analysis during the rise of novel COVID-19 cases in India.
- Analysis of translations of the Bhagavad Gita using sentiment analyses.
- Insights about topic modelling for Bhagavad Gita and Upanishads.

BACKGROUND

Sentiment Analysis

- Sentiment analysis is part of natural language processing, text analysis, computational linguistics, and biometrics.
- Sentiment analysis typically use language models to identify, extract, quantify, and study affective states (emotions).
- Sentiment analysis is used for marketing and advertising, analysing customer reviews and surveys, social media analysis, and applied to various domains including medicine and public health.

Topic Modelling

- Topic modelling is used for discovering abstract "topics" that occur in a collection of documents or text corpus.
- Topic modelling used text-mining tool for discovery of hidden semantic structures in a text body.
- A document typically concerns multiple topics in different proportions; hence, it is a challenge for naturally language processing algorithms and models given ambiguity in expressions (Twitter and social media) .
- Topic modelling is useful in social media analysis, understanding public behaviour during events such as elections. It has been useful for marketing and advertising.

Recurrent Neural Networks

The dynamics of the change of hidden state neuron activation in simple recurrent networks is given by the following.

$$y_i(t) = f\left(\sum_{k=1}^{K} v_{ik}\ y_k(t-1) + \sum_{j=1}^{J} w_{ij}\ x_j(t)\right)$$

where $y_k(t)$ and $x_j(t)$ represent the output of the context state neuron and input neurons respectively. v_{ik} and w_{ij} represent their corresponding weights. $f(.)$ is the transfer function.

Recurrent Neural Networks

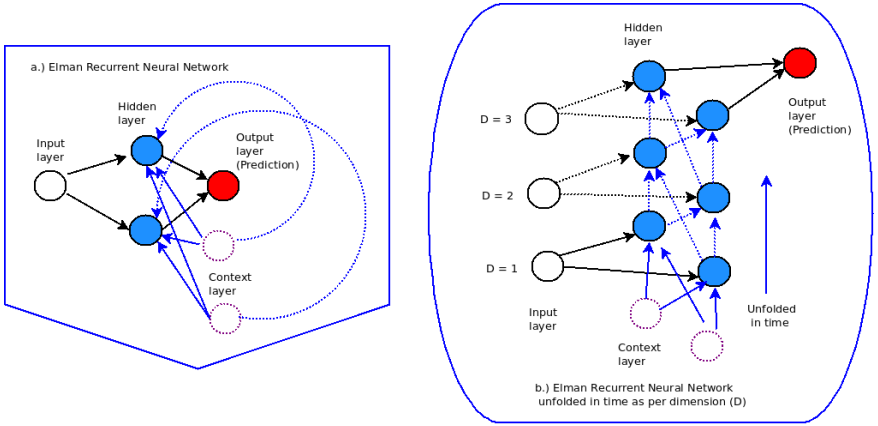


Figure: a) Elman RNN and b) Elman RNN unfolded in time. Source: Chandra, R. (2015). IEEE transactions on neural networks and learning systems, 26(12), 3123-3136

Recurrent Neural Networks

At times, we only need to look at recent information to perform the present task, such as a language model trying to predict the next word based on the previous ones. In such cases, where the gap between the relevant information and the place that it's needed is small, recurrent neural networks (RNNs) can learn to use past information.

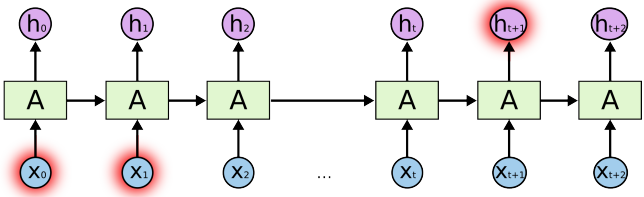


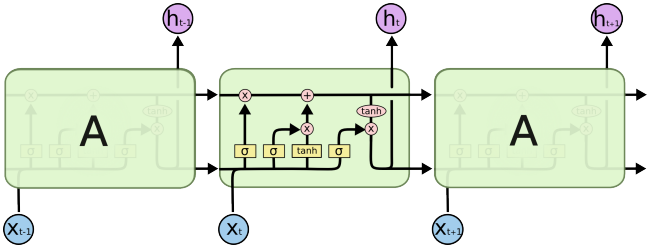
Figure: Vanishing gradient problem - long term dependencies [1]

[1] Source: https://colah.github.io/posts/2015-08-Understanding-LSTMs/

LSTM

There are also cases where we need more context where the gap between the relevant information and the point where it is needed to become very large. As that gap grows, RNNs have difficulty to learn to connect the information. The problem is known as the vanishing gradient problem where RNNs have difficulty to learn long term dependencies in sequences.

Long short-term memory (LSTM) networks address the vanishing gradient problem with memory cells.



LSTM

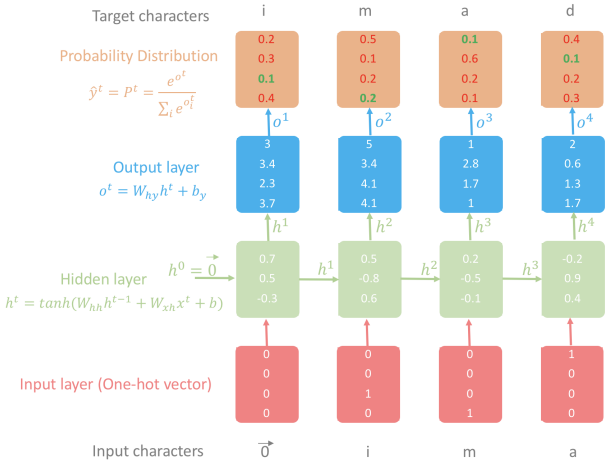


Figure: LSTM for Language modelling [3]

Transformers

- A transformer is an extended LSTM model that adopts the mechanism of attention which mimics cognitive attention to enhance important parts of the data while fading the rest.
- Transformers also use an encoder-decoder architecture and have mostly been used for NLP tasks such as translation and text summarising.
- In comparison to conventional RNNs, transformers do not require data to be processed in a sequential order since the attention operation provides context for any position in the input sequence.

Transformers

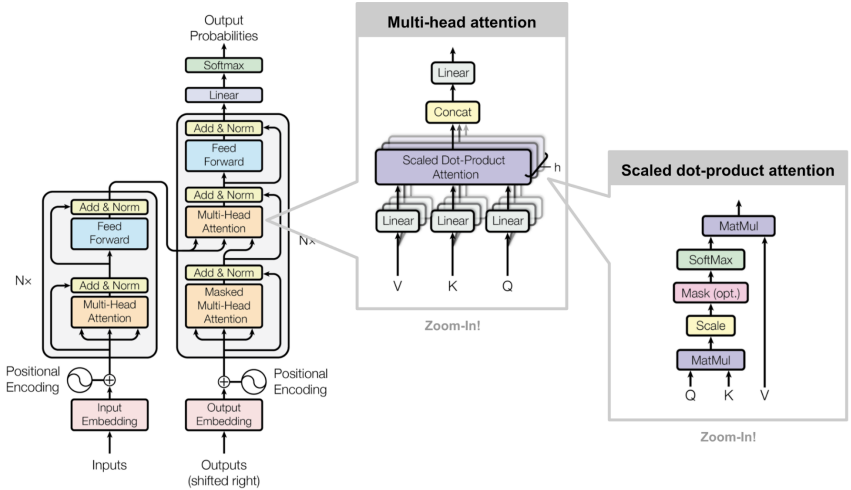


Figure: Transformers - specialised LSTM networks with attention mechanism.

BERT

Developed by Google, bidirectional encoder representations from Transformers (BERT) is pre-trained on a large corpus for language tasks.

- The original BERT has two models: 1.) BERT-base features 12 encoders with 12 bidirectional self-attention heads, and 2.) BERT-large features 24 encoders with 16 bidirectional self-attention heads.
- These are pre-trained from unlabeled data extracted from a corpus with 800 million words and English Wikipedia with 2,500 million words, respectively.
- Word2vec and GloVe are content-free models that generate a single word embedding representation for each word, whereas BERT takes into account the context for each occurrence of a given word which makes BERT one of the best language models.

BERT

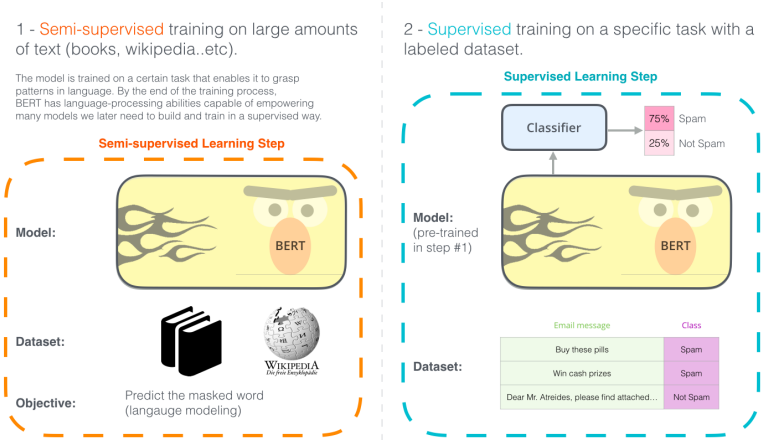


Figure: BERT for Language modelling [4]

[4] Source: https://jalammar.github.io/illustrated-bert/

APPLICATIONS

US General Elections - 2020

Figure: US 2020 Elections - Biden and Trump. Source: BBC

Social Media and Language Modelling

- Advancements of deep learning-based language models have been promising for sentiment analysis with data from social networks such as Twitter.
- Social media plays a crucial role in shaping the worldview during election campaigns. Social media has been used as a medium for political campaigns and a tool for organizing protests; some of which have been peaceful, while others have led to riots.
- Previous research indicates that understanding user behaviour, particularly in terms of sentiments expressed during elections can give an indication of the election outcome.

Election - Background

- The 2020 US Presidential election featured an intense competition between Democrat party candidate Joe Biden and Republican party candidate Donald Trump.
- Due to an intense campaign prior to the elections, there has been political unrest and fierce online activities during the first wave of COVID-19.
- President Donald Trump was banned by Twitter as it was alleged that his comments led the Capitol riots.

Election Modelling via Sentiment Analysis

- We present a framework that uses sentiment analysis via state-of-art language models to understand public behavior during elections.
- We employ BERT and LSTM-based language models for sentiment analysis.
- We use the internet movie database (IMDB) as training dataset that provides polarity scores indicating positive and negative sentiments.
- We investigate if sentiment analysis from social media can help in modelling and understanding voter behaviour during the elections.

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US General Elections - 2020

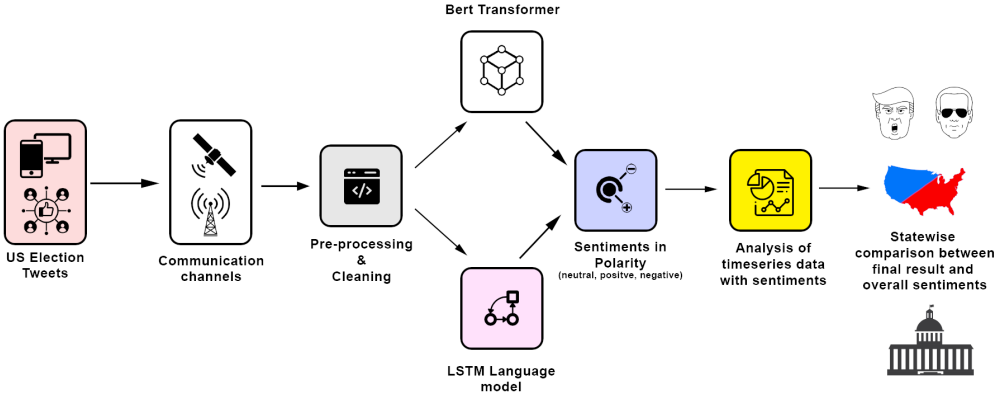


Figure: Framework for sentiment analysis based election modelling

US General Elections - 2020

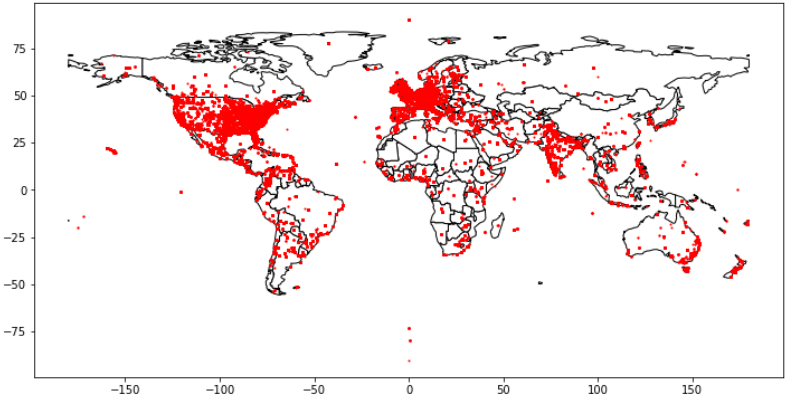


Figure: Data analysis - source of Tweets

US General Elections - 2020

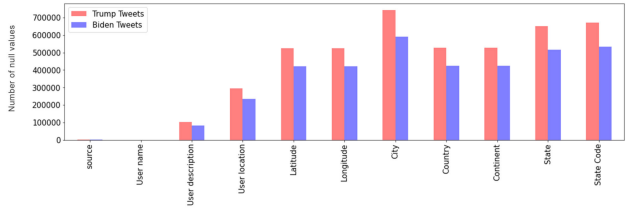


FIGURE 4. Number of missing (null) values present in tweets for the respective datasets (Trump and Biden) showing that there is mostly missing information regarding user location and further details given by city, country, state and continent. Note that this is giving further information about the "Geo Data not available (NA)" shown in Figure 3.

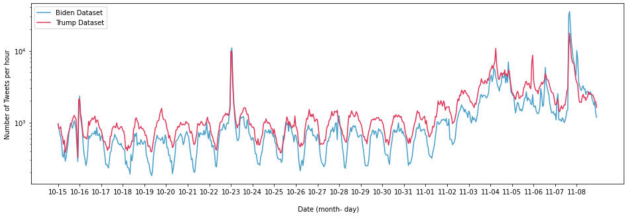


FIGURE 5. Tweet per hour from October 15th to 11th November, 2020.

US General Elections - 2020

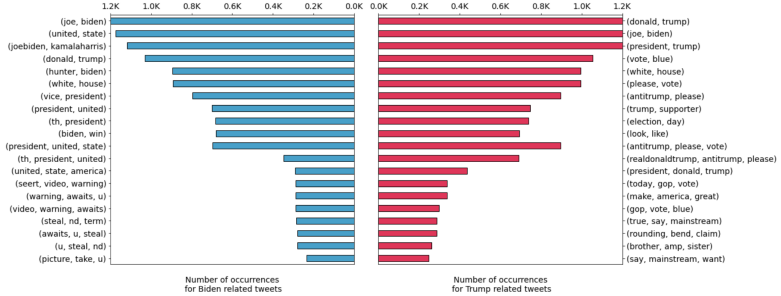
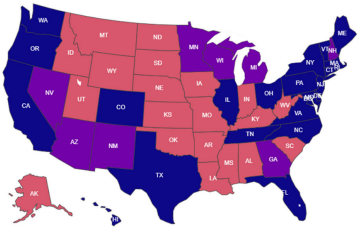
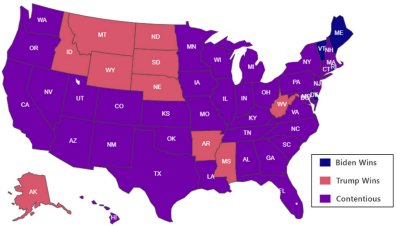


Figure: Top 10 bi-grams and tri-grams

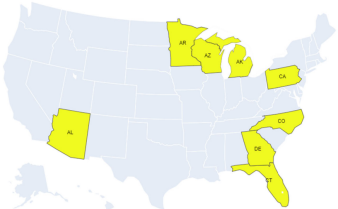
US General Elections - 2020



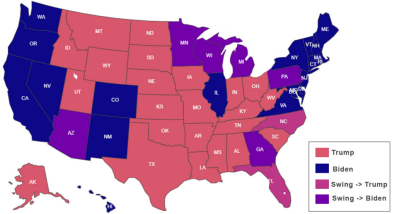
(a) BERT model predictions



(b) LSTM model predictions



(c) Major Swing States, 11th November 2020 [61]



(d) Actual Results, 15th December 2020 [62]

US General Elections - 2020

TABLE 4. Prominent state's average sentiment and their actual result comparison based on BERT model Figure 7 (Panel a and b).

Top 3 Positive State							
Donald Trump (Figure 7, Panel a)				Joe Biden (Figure 7, Panel b)			
State	Trump Score	Biden Score	Actual Result	State	Trump Score	Biden Score	Actual Result
Wyoming	0.106353	0.134895	Trump 70.4%	Delaware	-0.01333	0.164065	Biden 58.8%
New Hampshire	0.100506	0.086244	Biden 52.9%	North Dakota	-0.01333	0.163476	Trump 65.5%
Kentucky	0.074034	0.095935	Trump 62.1%	Wyoming	0.106353	0.134895	Trump 70.4%
Top 3 Least Positive State							
Donald Trump (Figure 7, Panel a)				Joe Biden (Figure 7, Panel b)			
State	Trump Score	Biden Score	Actual Result	State	Trump Score	Biden Score	Actual Result
Montana	-0.10017	0.097477	Trump 56.9%	West Virginia	0.003656	0.042460	Trump 68.6%
Delaware	-0.01333	0.164065	Biden 58.8%	Mississippi	0.014113	0.04309	Trump 57.5%
North Dakota	-0.00297	0.163476	Trump 65.5%	Utah	0.061679	0.050787	Trump 58.1%

TABLE 5. Swing state's average sentiment and their actual result comparison based on the BERT model. Note that either the polarity ratio [Biden/Trump, Trump/Biden] of less than 1.5 determines if the state will be contentious, which can give insights if the state will be a swing state.

States	Trump Score	Biden Score	B_{score}/T_{score}	T_{score}/B_{score}	Our Result	Actual Result
Arizona	0.053	0.069	1.307	0.765	Contentious	Trump 49.1%
Michigan	0.0573	0.077	1.355	0.738	Contentious	Biden 50.6%
Wisconsin	0.059	0.089	1.499	0.667	Contentious	Biden 49.4%
Minnesota	0.0428	0.063	1.483	0.674	Contentious	Biden 52.4%
Pennsylvania	0.029	0.088	2.973	0.336	Biden	Biden 50.0%
North Carolina	0.047	0.0942	2.018	0.495	Biden	Trump 49.9%
Florida	0.042	0.085	2.059	0.485	Biden	Trump 51.2%
Georgia	0.061	0.091	1.489	0.671	Contentious	Biden 49.5%

Figure: Predictions

US General Elections - 2020: Discussion

- We analyzed approximately 1.2 million tweets associated with the US 2020 presidential elections. After modeling and analyses, we found that sentiment analysis can form a general basis for modeling election outcomes.
- The BERT model indicated that Biden had a better chance of winning based on the tweets during the electoral campaigns. We find that the BERT model has been accurate in determining Trump, Biden, and the contentious states.
- Hence, given more data and geographical information, sentiment analysis could be helpful in predicting election results.
- Our model has a major limitation where it only provides a prediction based only on a small section of the society that expresses themselves on social media about their political views.

COVID-19 Sentiment Analysis

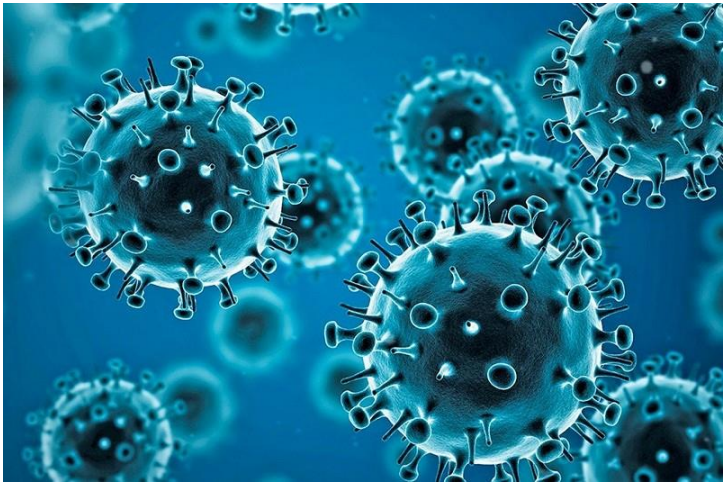


Figure: Visualisation of coronavirus. Source: WHO

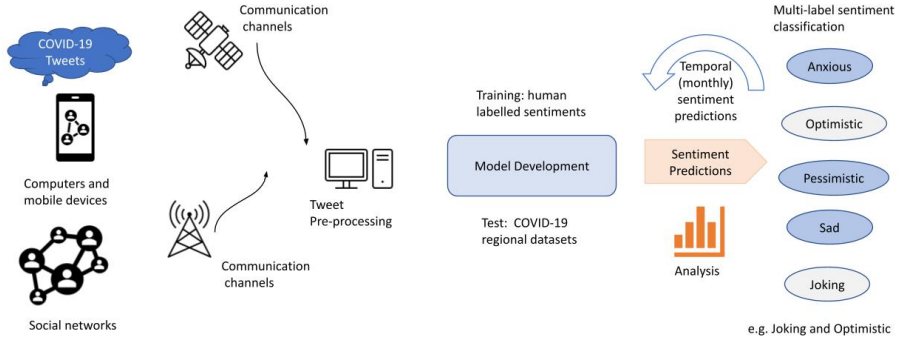
COVID-19 Sentiment Analysis

- The COVID-19 pandemic is a catastrophic event that has raised a number of psychological issues such as depression given abrupt social changes and lack of employment.
- During the rise of COVID-19 cases with stricter lock-downs, people have been expressing their sentiments in social media. This can provide a deep understanding of human psychology during catastrophic events.
- We present a framework that employs deep learning-based language models via long short-term memory (LSTM) recurrent neural networks for sentiment analysis during the rise of novel COVID-19 cases in India.
- The framework features LSTM language model with a global vector embedding and state-of-art BERT language model.

COVID-19 Sentiment Analysis

- We review the sentiments expressed for selective months in 2020 which covers the first major peak of novel cases in India.
- Our framework utilises multi-label sentiment classification where more than one sentiment can be expressed at once.

COVID-19 Sentiment Analysis



COVID-19 Sentiment Analysis

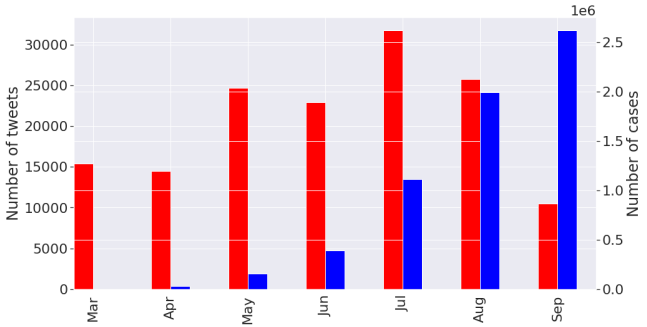


Figure: Data analysis - Tweets in India. The red bars indicate the number of tweets while the black bars indicate the number of novel cases.

COVID-19 Sentiment Analysis

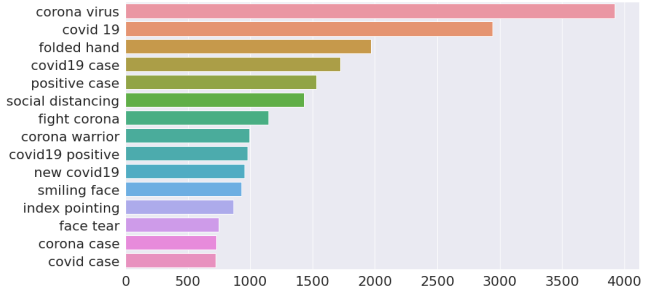


Figure: Top bi-grams

COVID-19 Sentiment Analysis

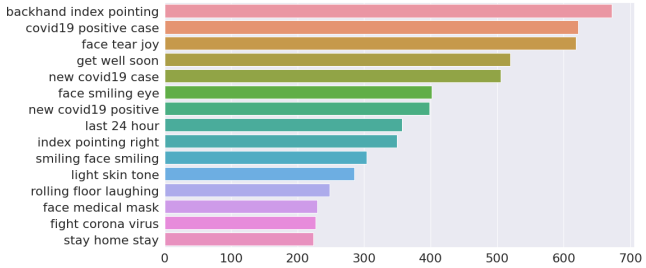


Figure: Top tri-grams

COVID-19 Sentiment Analysis

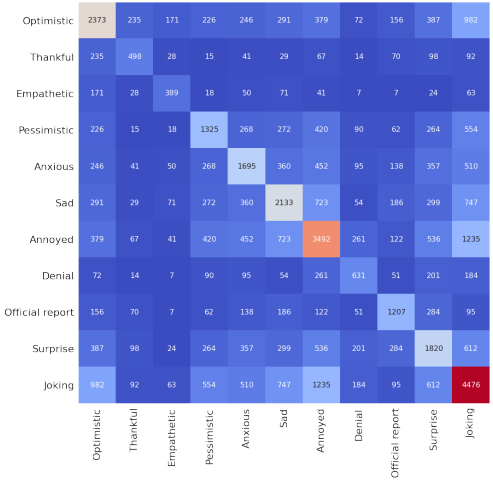


Figure: Senwave hand-labelled data for training

COVID-19 Sentiment Analysis

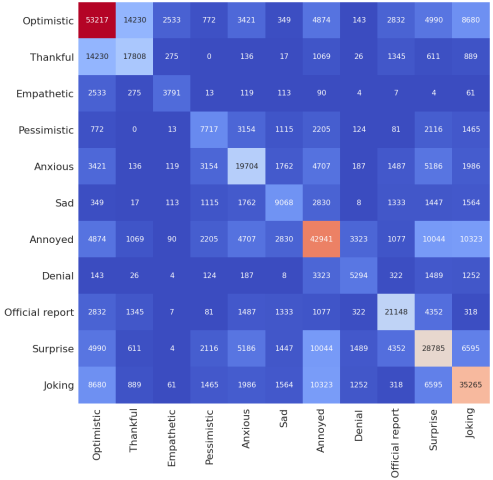


Figure: Predictions - India

COVID-19 Sentiment Analysis

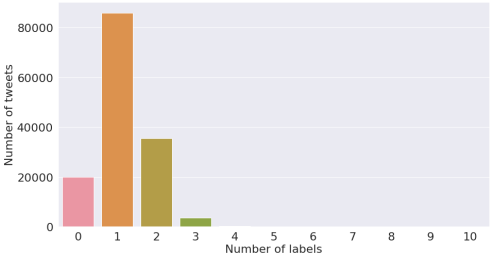


Figure: Multiple sentiments at once.

COVID-19 Sentiment Analysis

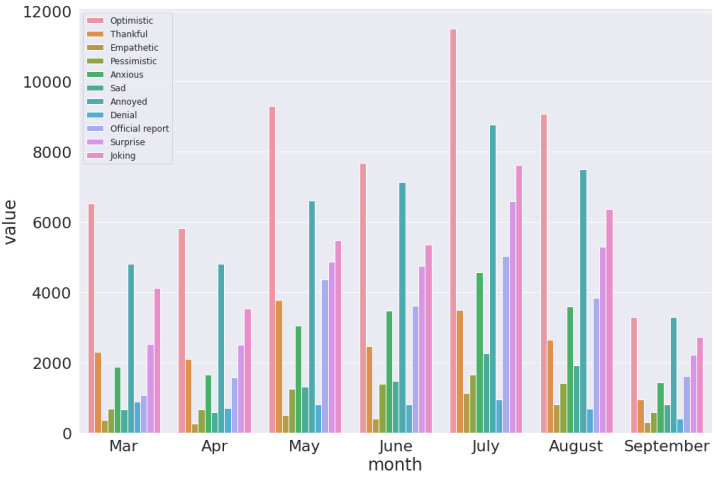


Figure: Monthly predictions - India

COVID-19 Sentiment Analysis

- Our investigation revealed that majority of the tweets have been "optimistic", "annoyed" and "joking" that expresses optimism, fear and uncertainty during the rise of the COVID-19 cases in India.
- The number of tweets significantly lowered towards the peak of new cases. Furthermore, the optimistic, annoyed and joking tweets mostly dominated the monthly tweets with much lower number of negative sentiments expressed.
- We found that most tweets that have been associated with "joking" were either "optimistic" or "annoyed", and minority of them were also "thankful". In terms of the "annoyed" sentiments in tweets, mostly were either "surprised" or "joking".
- These predictions generally indicate that although the majority have been optimistic, a significant group of population has been annoyed towards the way the pandemic was handled by the authorities.

Analysis of Hindu texts

Analysis of translations: Bhagavad Gita

- The Bhagavad Gita is an ancient Hindu philosophical text originally written in Sanskrit that features a conversation between Lord Krishna and Arjuna prior to the Mahabharata war. The Bhagavad Gita is also seen as a holy text by Hindus which serves as the forefront of the Vedic corpus of Hinduism.
- In the last two centuries, there have been a lot of interest in Hindu philosophy by western scholars and hence the Bhagavad Gita has been translated in a number of languages. However, there is not much work that validates the quality of the English translations and compares them.

Analysis of Hindu texts

Figure: Bhagavad Gita - Viraat Roop of Lord Krishna

Translations of the Bhagavad Gita

- Recent progress of language models powered by deep learning has enabled not only translations but better understanding of language and texts with semantic and sentiment analysis. Our work is motivated by the recent progress of language models powered by deep learning methods.
- We compare selected translations (mostly from Sanskrit to English) of the Bhagavad Gita using semantic and sentiment analyses.

Texts	Translator	Year
The Gita according to Gandhi[83]	Mahatma Gandhi & Mahadev Desai	1946
The Bhagavad Gita[84]	Eknath Easwaran	1985
The Bhagavad Gita[85]	Shri Purohit Swami	1935

Analysis of translations: Bhagavad Gita

Bhagavad Gita: Chapter 3 - verse 37-39

- "37. It is desire, it is aversion, born of passion. Desire consumes and corrupts everything. It is man's greatest enemy. 38. As fire is shrouded in smoke, a mirror by dust and a child by the womb, so is the universe enveloped in desire. It works through the senses, the mind and the reason; and with their help destroys wisdom and confounds the soul. 39. Therefore, O Arjuna, first control thy senses and then slay desire, for it is full of sin, and is the destroyer of knowledge and of wisdom. " - Sri Purohit Swami
- "37. It is Lust, it is Wrath, born of the guna—Rajas. It is the arch-devourer, the arch-sinner. Know this to be man's enemy here. 38. As fire is obscured by smoke, a mirror by dirt, and the embryo by the amnion, so is knowledge obscured by this. 39. Knowledge is obscured, O Kaunteya, by this eternal enemy of the wise man, in the form of Lust, the insatiable fire." - Mahatma Gandhi

Analysis of translations: Bhagavad Gita

Bhagavad Gita: Chapter 6 - verse 36

- "It is not possible to attain Self-Realisation if a man does not know how to control himself; but for him who, striving by proper means, learns such control, it is possible." - Sri Purohit Swami
- "Without self-restraint, yoga, I hold, is difficult to attain; but the self-governed soul can attain it by proper means, if he strives for it." - Mahatma Gandhi

Analysis of translations: Bhagavad Gita

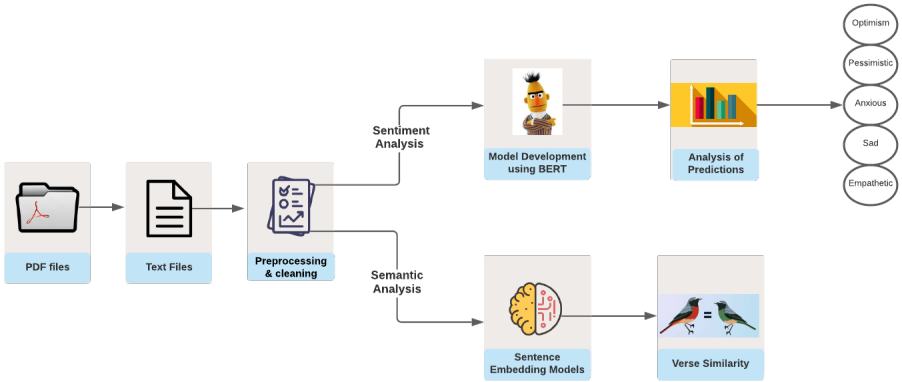


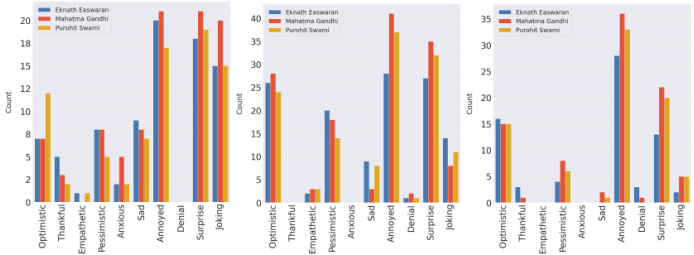
Figure: Framework

Analysis of translations: Bhagavad Gita

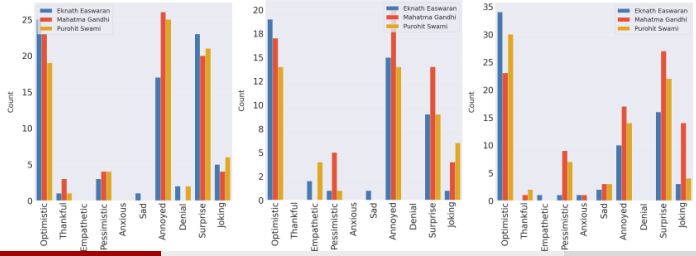
Original sentence	Transformed sentence
1. If, O Janardana, thou holdest that the attitude of detachment is superior to action, then why, O Keshava, dost thou urge me to dreadful action?	If, O Krishna, you hold that the attitude of detachment is superior to action, then why, O Krishna, do you urge me to dreadful action?
27. Whatever thou doest, whatever thou eatest, whatever thou offerest as sacrifice or gift, whatever austerity thou dost perform, O kaunteya, dedicate all to Me.	Whatever you do, whatever you eat, whatever you offer as sacrifice or gift, whatever austerity you do perform, O Arjuna, dedicate all to Me.
7. Yet since with mortal eyes thou canst not see Me, lo! I give thee the Divine Sight. See now the glory of My Sovereignty."	Yet since with mortal eyes you can not see Me, lo! I give you the Divine Sight. See now the glory of My Sovereignty."
3. Thou art the Primal God, the Ancient, the Supreme Abode of this universe, the Knower, the Knowledge and the Final Home. Thou fillest everything. Thy form is infinite.	You are the Primal God, the Ancient, the Supreme Abode of this universe, the Knower, the Knowledge and the Final Home. You fill everything. Your form is infinite.

Figure: Text pre-processing

Predictions by Chapter across translations



(a) Chapter 1: The War Within (b) Chapter 2: Self-Realization (c) Chapter 3: Selfless Service



Prediction - Sentiments in the Bhagavad Gita

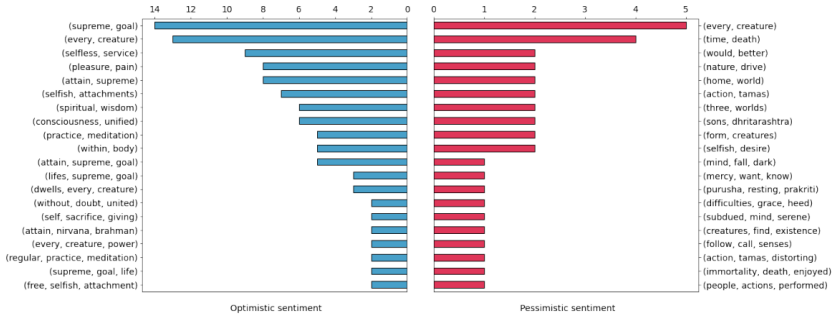
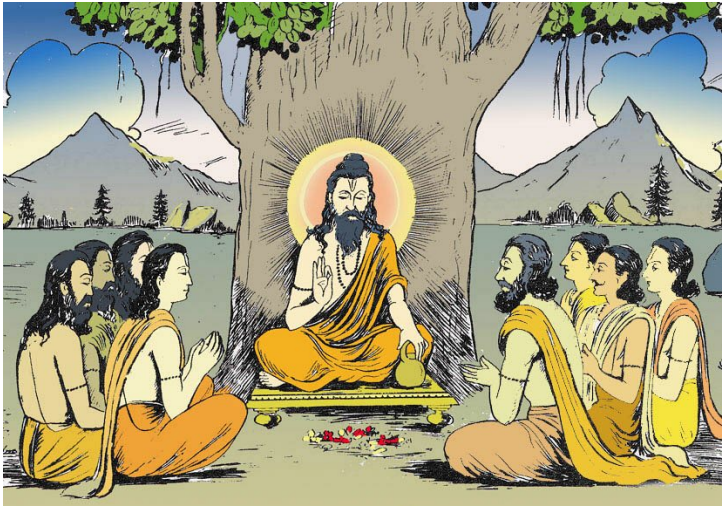


Figure: Top 10 optimistic and pessimistic Bi-grams and Tri-grams from processed verses for Eknath Easwaran's translation

Topic Modelling: Bhagavad Gita and Upanishads



Topic Modelling: Bhagavad Gita and Upanishads

- A distinct feature of Hindu religious and philosophical text is that they come from a library of texts rather than single source.
- The Upanishads is known as one of the oldest philosophical texts in the world that forms the foundation of Hindu philosophy.
- The Bhagavad Gita is core text of Hindu philosophy and is known as a text that summarises the key philosophies of the Upanishads with major focus on the philosophy of karma.
- These texts have been translated into a number of languages and there exists studies about themes and topics that are prominent; however, there is not much study of topic modelling using language models which are powered by deep learning.
- We use advanced language produces such as BERT to provide topic modelling of the key texts of the Upanishads and the Bhagavad Gita.

Quotes on the Upanishads

- "I go into the Upanishads to ask questions." - Niels Bohr
- "There is no kind of framework within which we can find consciousness in the plural; this is simply something we construct because of the temporal plurality of individuals, but it is a false construction....The only solution to this conflict insofar as any is available to us at all lies in the ancient wisdom of the Upanishad." - Erwin Schrödinger
- "As we study the philosophy of the Upanishads, the impression grows on us that the attainment of this path is not exactly the simplest of tasks. Our Western superciliousness in the face of these Indian insights is a mark of our barbarian nature, which has not the remotest inkling of their extraordinary depth and astonishing psychological accuracy." - Carl Jung

Selected verses from the Upanishads

- "What is the cause of the cosmos? Is it Brahman? From where do we come? By what live? Where shall we find peace at last? What power governs the duality of pleasure and pain by which we are driven?" - Svetasvatara Upanishad
- "You are what your deep, driving desire is. As your desire is, so is your will. As your will is, so is your deed. As your deed is, so is your destiny." - Brihadaranyaka Upanishad
- "Knowledge is two-fold, higher and lower. The study of the Vedas, linguistics, Rituals, astronomy, and all the arts can be called lower knowledge. The higher is that which lead to Self-realization." - Mundaka Upanishad

Topic Modelling: Bhagavad Gita and Upanishads

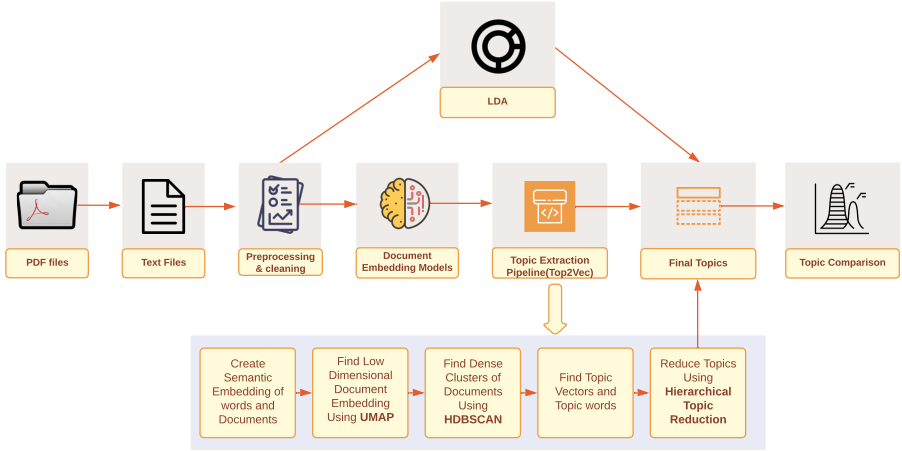
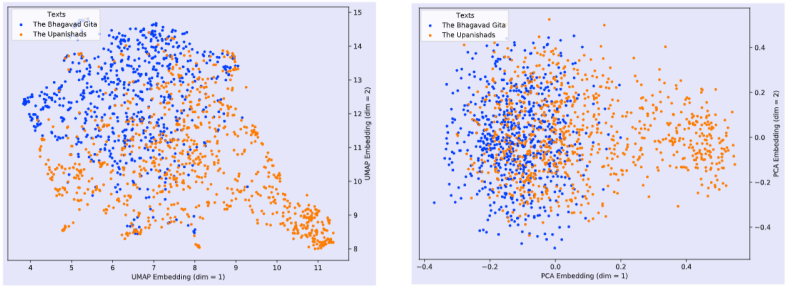


Figure: Framework

Topic Modelling: Bhagavad Gita and Upanishads



(a) UMAP Embeddings **(b)** PCA Embeddings

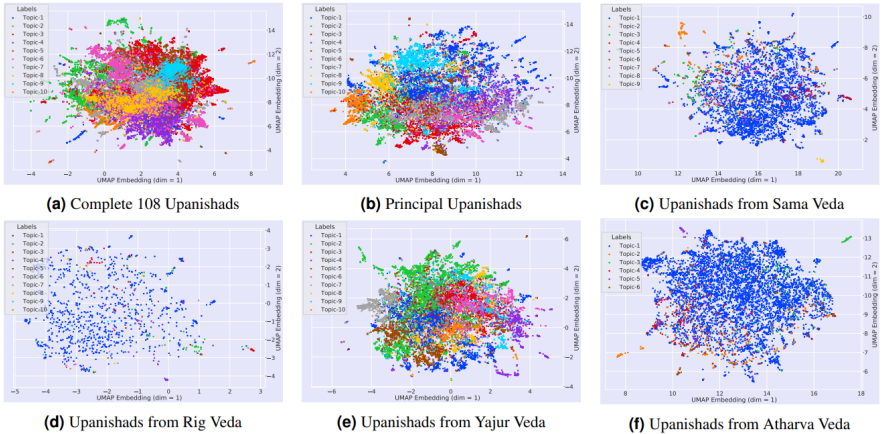
Figure: Comparison of Bhagavad Gita and Upanishads with respect to topics discovered.

Topic Modelling: Bhagavad Gita and Upanishads

Topics of Upanishads	ID	Most Similar topics in Gita	ID	Similarity
hinduism,hindu,buddhism,bhagavad,buddhi	1	eternal,eternity,immortality,immortal,universe	13	0.55
immortality,immortal,deathlessness,everliving	2	immortality,immortal,deathless,mortality,death	4	0.89
selfless,selfsame,self,selflessly,selfs	3	selfless,selfishly,selfish,selflessly,selfrealization	1	0.77
loveliness,loving,love,loves,loved	4	sacrifices,sacrifice,devotion,worship,sacrificing	8	0.79
asks,asked,ask,divine,buddhism,answered	5	arjuna,gandharvas,dharma,ashvattha,adhiyajna	2	0.67
knowledge,ignorance,wisdom,cognitive,cognition	6	understanding,understands,understand,comprehension	6	0.74
heart,hearts,immortality,immortal,eternal	7	eternal,eternity,immortality,immortal,universe	13	0.71
meditate,meditated,meditates,spiritually,spiritual,	8	sacrifices,sacrifice,devotion,worship,sacrificing	8	0.76
feeding,hunger,feed,hungry,eating	9	universe,nonexistence,infinite,immortality	7	0.64
dreamless,unconscious,consciousness,dreaming,sleeping	10	spiritually,consciousness,cheerfulness,spiritual,gratification	3	0.68
self,selfsame,selflessly,selfs,selfless	11	meditation,meditate,spiritually,spiritual,consciousness	9	0.70
selflessly,selfless,oneself,selfsame,untruth	12	universe,nonexistence,infinite,immortality,cosmic	7	0.64
consciousness,happiness,enjoyment,happy,vividness	13	spiritually,consciousness,cheerfulness,spiritual,gratification	3	0.75
sunrise,starlight,solar,sun,moon	14	universe,gods,divine,immortal,immortality	11	0.55
sunrise,sun,dawn,daylight,suns	15	sacrifices,sacrifice,devotion,worship,sacrificing	8	0.62
brahman,brahmanas,brahmanic,brahmins,brahmin	16	ignorance,ignorant,unwise,wisdom,unkindness	5	0.64
brahman,brahmanas,bhagavad,mahabharata,meditate	17	meditation,meditate,spiritually,spiritual,consciousness	9	0.54
brahman,meditate,meditated,mantram,meditates	18	eternal,eternity,immortality,immortal,universe	13	0.58

Figure: Topics discovered

Topic Modelling: Bhagavad Gita and Upanishads



(a) Complete 108 Upanishads **(b)** Principal Upanishads **(c)** Upanishads from Sama Veda

(d) Upanishads from Rig Veda **(e)** Upanishads from Yajur Veda **(f)** Upanishads from Atharva Veda

Figure: Application to 108 Upanishads - and larger Vedic corpus

Limitations and Challenges

- Availability of data - with geo-information (COVID-19 and Election Modelling).
- Interpretation of conversational expressions and language (Twitter).
- Interpretation of poetry - songs translated from ancient languages.
- Limitation of language models for modelling Indian languages - Hindi and Sanskrit.
- Collaboration with humanities - lack of funding for humanities research in Australia.
- Recognition of inter-disciplinary humanities research by scientific journals.
- Being misrepresented as a priest or theologian when studying philosophy of religion.

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Future Work

- COVID-19 Antivaxxer sentiments in Twitter during COVID-19 modelling done - paper to appear online 2022 - in collaboration with CSIRO).
- Language models for understanding and analyses of patient experience in Australian hospitals (acquiring data stage).
- Topic modelling in evolution of ancient poetry and songs (planned).
- Political biasness in media reporting (planned).

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Thanks

- Please note all projects have open software and data published via Github.