Artificial intelligence for topic modelling in Hindu philosophy: mapping themes between the Upanishads and the Bhagavad Gita

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Abstract

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 many 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. In this paper, we use advanced language produces such as BERT to provide topic modelling of the key texts of the Upanishads and the Bhagavad Gita. We analyse the distinct and overlapping topics amongst the texts and visualise the link of selected texts of the Upanishads with Bhagavad Gita. Our results show a very high similarity between the topics of these two texts with the mean cosine similarity of 73%. We find that out of the fourteen topics extracted from the Bhagavad Gita, nine of them have a cosine similarity of more than 70% with the topics of the Upanishads. We also found that topics generated by the BERT-based models show very high coherence as compared to that of conventional models. Our best performing model gives a coherence score of 73% on the Bhagavad Gita and 69% on The Upanishads. The visualization of the low dimensional embeddings of these texts shows very clear overlapping among their topics adding another level of validation to our results.

Author summary

Introduction

Philosophy of religion [1,2] is a field of study that covers key themes and ideas in religions and culture that relate to philosophical topics such as ethics and metaphysics. Hindu philosophy [3–5] consists of schools developed for thousands of years which focus on themes such as ethics [6], consciousness [4], karma [7,8], logic and ultimate reality [5]. Hindu philosophy is at times referred as Indian philosophy [9,10]. The philosophy of karma and reincarnation are central to Hindu philosophy [10]. The Upanishads form the key texts of Hindu philosophy and seen as the conclusion of the Vedas [11,15]. Hindu
philosophy consists of six major theistic (Astika) schools include Vedanta, Samkhya, Vaisheshika, Mīmāṃsā, and Yoga. Moreover, Jain, Buddhist, Carvaka, and Ājīvika philosophy are the major agnostic and atheistic (Nastika) schools of Hindu philosophy. There has been a lot of interest of Hindu philosophy, particularly in the west, with a large list bibliography of translations of key texts such as the Upanishads. Moreover, Hindu and Buddhist philosophy have parallels with development of specific themes in Greek philosophy.

The Upanishads and Bhagavad Gita are the foundational texts for Hindu philosophy. These texts have been written much later in verse form in Sanskrit language, they have been sung and remembered for thousands of years in the absence of a writing system. The Bhagavad Gita is part of the Mahabharata which is known as the one of oldest and largest epics written in verse in the Sanskrit language. The Bhagavad Gita is known as a concise summary of Hindu philosophy with major attribute which is the philosophy of karma. The Upanishads is a collection of philosophical texts of ancient India which marks the foundation in the history of philosophy. There are 108 key Upanishads of which some were lost in time. There are 12 are prominent and have been well studied by western scholars.

Nowadays, natural language processing (NLP) methods, that focuses in processing and modelling language are typically implemented via deep learning. NLP considers tasks such as topic modelling, language translation, speech recognition, semantic and sentiment analysis. Sentiment analysis provides an understanding of human emotions and affective states. Recurrent neural networks such as long-short term memory (LSTM) network models have been prominently used as language models due to their capability to model temporal sequences. LSTM models have been improved for language modelling using attention based mechanisms, and encoder-decoder LSTM framework with attention. Bidirectional encoder representations from Transformer (BERT) model is a state-of-art pre-trained language model that features more than 300 million model parameters for language modeling tasks. Topic models help us better understand a text corpus by extracting the hidden topics. Traditional topic model such as linear discriminant analysis (LDA) assumes that documents are a mixture of topics and each topic is a mixture of words with certain probability score. Sentence BERT (S-BERT) improves BERT model by reducing computational time to derive semantically meaningful sentence embedding. Recent topic modelling frameworks use S-BERT for embedding in combination with clustering methods. BERT-based models have shown promising results for topic modelling, which motivates their usage in our study.

Religious linguistics refer to the study of religious sentences and utterances. Major aim of the religious linguistic research is to create an analysis of various subject matters related to religious sentences which include God, miracles, redemption, grace, holiness, sinfulness along with several other philosophical interpretations. Most translations of the Bhagavad Gita and related texts come with interpretations and commentary regarding philosophy and how the verses relate to issues at present. Stein presented a study about multi-worded expressions by extracting local grammars based on semantic classes in the Spanish translation of the Bhagavad Gita and found it to be promising for understanding religious texts and their literary complexity. The role of multi-word expressions (MWE) could be a way to better understand metaphorical and lyrical style of the Bhagavad Gita. Rajendran presented a study on metaphors in Bhagavad Gita using text analysis based on conceptual metaphor theory (CMT). The analysis identified the source and target domains for the metaphors, and traced the choice of metaphors to physical and cultural experiences. The metaphors have been inspired by the human body and ancient India.
which resonate with modern times. Rajput et al. [64] provided a statistical study of the word frequency and length distributions prevalent in the translations of Bhagavad Gita in Hindi, English and French from the original composition in Sanskrit. The Shannon entropy-based measure estimated the vocabulary richness with Sanskrit as the highest, and word-length distributions also indicated Sanskrit having longest word length. Hence, the results demonstrated the inflectional nature of Sanskrit. Dewi [65] studied metaphorical expressions and the conceptual expression underlying in them by reviewing 690 sentences related to metaphor of life from Bhagavad Gita and analyzed them using some conceptual metaphor theory. It was reported that the Bhagavad Gita featured 24 conceptual metaphors among which life is an entity, life is a journey and life is a continuous activity are the most frequent ones. Bhuwak [66] examined specific ideas from Bhagavad Gita such as cognition, emotion, and behaviour by connecting them with the context of human desire. It was reported that desires lead to behaviour and achievement or non-achievement of desire lead to positive and negative emotions which can be managed in a healthy way by self-reflection, contemplation and the practice of karma yoga (selfless action). In our earlier work, BERT-based language model framework was used for sentiment and semantic analysis as a means to compare three different Bhagavad Gita translations where it was found that although the style and vocabulary differ vastly, the semantic and sentiment analysis shows similarity of majority of the verses [67].

Although the Bhagavad Gita and Upanishads have been translated into a number of languages and studies about their central themes and topics have been prominent, there is not much work in utilising latest advancements from artificial intelligence, such as topic modelling using language models – powered by deep learning. In this paper, we use advanced language models such as BERT in a framework to provide topic modelling of the key texts of the Upanishads and the Bhagavad Gita. We analysis the distinct and overlapping topics amongst the texts and visualise the link of selected texts of the Upanishads with Bhagavad Gita. Our major goal is to map the topics in the Bhagavad Gita with the Upanishads; since it is known that the Bhagavad Gita summarizes the key messages in the Upanishads and there are studies about the parallel themes in both texts [68]. We also provide a comparison of the proposed framework with LDA which have been prominent for topic modelling.

The rest of the paper is organised as follows. In Section 2, we provide further details about background behind the Bhagavad Gita and Upanishads. Section 3 presents the methodology that highlights model development for topic modelling. Section 4 presents the results and Section 5 provides a discussion and future work.

1 Background

1.1 BERT language model

BERT is an attention-based Transformer model [44] for learning contextualized language representation where the vector representation of the every input token is dependent on the context of its occurrence in a sentence. The Transformer model [44] has been developed by using long short-term memory (LSTM) recurrent neural networks [42] with an encoder-decoder architecture [70]. Transformer models implement the mechanism of attention by weighting the significance of each part of the input data which has been then prominent for language modelling tasks [44][71].

BERT is first trained to understand the language (called pre-training phase) and the context after that it is fine-tuned to learn the specific task such as neural machine translation (NMT) [46][72][76], question answering [77][82] and sentiment analysis [83][87]. The pre-training phase of BERT involve two different NLP tasks such
as masked language modelling (MLM) \cite{46, 88, 89} and next sentence prediction (NSP) \cite{46}. MLM and NSP are semi-supervised learning tasks. In MLM, 15% words in each input sequence is randomly replaced with a mask token and the model is trained to predict these randomly masked input sequences based on the context provided by the neighbouring non-masked words. In NSP, the BERT model learns to predict if two sentences are adjacent to each other. In this way a BERT model is trained simultaneously to minimize the combined loss function, and hence learn the contextualized word embedding. In the fine tuning-phase one or more fully connected layers are added on the top of final BERT layer based upon the applications. Since BERT is pre-trained, it can be more easily trained further with datasets for specific applications. In our earlier works, BERT-based framework has been used for sentiment analysis of COVID-19 related tweets during the rise of novel cases in India \cite{90}. Similar framework using BERT was used for modelling US 2020 presidential elections with sentiment analysis from Tweets in order to predict the state-wise winners \cite{91}.

Based upon the number of transformer blocks BERT \cite{46} is available with two variants: 1.) \textit{BERT BASE} consists of 12 transformer blocks stacked on top of each other with a hidden dimension embedding of 768 and 12 Attention heads, on the other hand 2.) \textit{BERT LARGE} consists of 24 transformer blocks with a hidden dimension embedding of 1024 and 16 attention heads. \textit{BERT BASE} has a total of 110 Million parameters while \textit{BERT LARGE} has a total of 340M parameters. BERT takes into account the context for each occurrence of a given word, in comparison to context-free models such as word vectors (word2vec) \cite{92} and global vector (GloVe) \cite{93} generate a single word embedding representation for each word in the vocabulary.

### 1.2 Document embedding models

The \textit{universal-sentence-encoder} \cite{94} is a sentence embedding model that encodes sentences into high-dimensional embedding vectors that can be used for various natural language processing tasks. The model takes a variable length English text as an input and gives 512-dimensional output vector. The model is trained with deep averaging networks (DANs) \cite{95} encoder, which simply takes the average of the input embeddings for words and bi-grams and then pass them through one or more deep neural networks to get the sentence embeddings. \textit{Sentence-BERT} (S-BERT) \cite{48} extends the BERT model and Siamese and triplet network \cite{96} to generate the sentence embeddings. S-BERT uses BERT embeddings with a pooling layer to get the sentence-embedding ($u$ and $v$) of two sentences. S-BERT has been fine tuned with objective functions such as triplet loss function and cosine similarity between $u$ and $v$.

### 1.3 Clustering techniques

Clustering is a type of unsupervised machine learning that groups unlabelled data based on a given similarity measure for a given dataset $x^{(1)}, ..., x^{(n)}$, where $x^{(i)} \in \mathbb{R}^d$ is a d-dimensional data point from the dataset. The goal of clustering is to assign each data-point a label or a cluster identify. A large number clustering algorithms exits in literature and we used two of them explained below for this work. Xu et al. \cite{97} presented an exhaustive list of different groups of clustering algorithms that includes: 1.) centroid based algorithms such as k-means clustering \cite{98}, regards the centroid of data point as the centroid of the corresponding clusters; 2.) hierarchical based algorithms such as agglomerative clustering \cite{99} which creates a hierarchical relationship among the data points in order to cluster them; 3.) density based algorithms that connects an area with high density into clusters \cite{100}; 4.) distribution based clustering such as Gaussian mixture model \cite{101} that assumes that data generated from same distribution belongs to the same clusters.
**K-means clustering** clusters n-data points into k-clusters, where each data point belongs to the cluster with the nearest mean. The k-means algorithm can be explained in the three steps. First step involves initialization of k-centroid corresponding to each clusters. In the second step a point is assigned to the closest cluster centroid. In the third step, centroid for each cluster is recalculated based on new assigned data points and step 2 and 3 is repeated till convergence.

**Hierarchical density based spatial clustering of application with noise (HDBSCAN)** is a density-based hierarchical clustering algorithm that defines clusters as highly dense regions separated by sparse regions. The goal of the algorithm is to find high probability density regions which are our clusters. It starts with estimating the probability density of the data by using the distance of the $k^{th}$ nearest neighbors, defined as the core distance $core_k(x)$. If a region is dense, then the distance of $k^{th}$ nearest neighbor will be less since more data point will fit in the region of small radius. Similarly, for the sparse region,a larger radius would be used. A distance metric called **mutual-reachability-distance** between two points $a$ and $b$ is defined in order to formalize this idea of density and is given by Equation 1.

$$d_{\text{mreach-k}}(a, b) = \max \{core_k(a), core_k(b), d(a, b)\}$$  \hspace{1cm} (1)

where $d(a, b)$ gives the euclidean distance between point $a$ and $b$. This mutual reachability distance is used to find the dense areas of the data but since the dense areas are relative and different clusters (dense areas) can have different densities, the entire data points can be modelled as a weighted graph with weight $d_{\text{mreach-k}}(a, b)$ of edge between nodes $a$ and $b$.

**1.4 Dimensionality reduction techniques**

Uniform manifold approximation and projection (UMAP) for dimension reduction is a non-linear dimensionality reduction technique which is constructed from the theoretical framework based on Riemannian geometry and algebraic topology. The detailed theoretical explanation of the algorithm is out of scope of this paper and can be seen in the paper of McInnes et al. UMAP can be used in a way similar to t-distributed stochastic neighbor embedding (t-SNE) and principal component analysis (PCA) for dimensionality reduction and to visualize high dimensional data.

Latent dirichlet allocation (LDA) is a generative probabilistic model for the topic modelling of the corpus based on word frequency. The basic idea behind the model is that, each document is generated by a statistical generative process and hence each document can be modelled as a random mixture of latent topics and each topic is mixture of words characterised its distribution. A word denoted by $w$ and indexed from 1 to the vocabulary size $V$ and a document is given by $w = \{w_1, w_2, ..., w_N\}$, where $w_i$ is the $i^{th}$ word in the sequence. The generative process involved in the algorithm can be summarized as 1.) fix the number of topic and hence the dimensionality of the Dirichlet distribution and that of the topic variable $z$ and sample $\theta$(per-document topic proportion) from a Dirichlet prior $Dir(\alpha)$ 2.) sample a topic $z_n$ from a multinomial distribution $p(\theta; \alpha)$ and then 3.) sample a word $w_n$ from multinomial probability distribution conditioned on $z_n, p(w_n|z_n, \beta)$. Overall probability of document $w$ containing $N$ words can be given by Equation 2.

$$p(w) = \int_{\theta} \left( \prod_{n=1}^{N} \sum_{z_n=1}^{k} p(w_n | z_n; \beta) p(z_n | \theta) \right) p(\theta; \alpha) d\theta$$  \hspace{1cm} (2)

Given a corpus of $M$ documents $D = \{w_1, ..., w_M\}$, the EM algorithm can be used to learn the parameters of an LDA model by maximizing a variational bound on $p(D)$,
Table 1. Details of the texts used for topic modelling.

| Texts                          | Translator                     | Year  |
|--------------------------------|--------------------------------|-------|
| The Bhagavad Gita [109]        | Eknath Easwaran                | 1985  |
| The Upnishads [110]            | Eknath Easwaran                | 1987  |
| The Ten Principal Upanishads   | Shri Purohit Swami & W.B. Yeats| 1938  |
| 108 Upanishads [113]           | The International Gita Publication | –     |

as seen in Equation 3

\[
\log p(D) \geq \sum_{m=1}^{M} E_{q_m} [\log p(\theta, z, w)] - E_{q_m} [\log q_m(\theta, z)] \tag{3}
\]

LDA has been used for several language modeling tasks that include the study of the relationship between two corpora using topic modeling [108] which is also the focus of our study.

2 Methodology

2.1 Datasets

We evaluated a number of prominent translations of the Bhagavad Gita and the Upanishads. In order to maintain the originality of the themes and ideas of these two classical Indian texts, we used the older and the most popular translations for this work. We chose Eknath Easwaran’s translation since he directly translated from Sanskrit to English and translated both texts [109,110], hence it would be not be creating a translation bias for topic modelling and comparison of the topics between the texts. Eknath Easwaran (1910 – 1999) was a professor of English literature in India and later moved to the United States where he translated these texts. In addition, we chose the translation by Shri Purohit Swami and William Butler Yeats [111] for further comparison. W. B Yeats (1865 – 1939) was Irish poet, dramatist, prose writer and known as one of the foremost figures of 20th-century literature. Shri Purohit Swami (1882 – 1941) was a Hindu teacher from Maharashtra, India. The translation of the Upanishads by them is special since it has been done jointly by prominent Indian and Irish scholars and captures Eastern and Western viewpoints. Table[1]provides further details of the texts. Note that Shri Purohit Swami also translated the Bhagavad Gita [112] which can be used in future analysis, and not used in this work.

The Bhagavad Gita consist of 18 chapters which features a series of questions and answers between Lord Krishna and Arjuna that range with a range of topics that includes the philosophy of Karma. The Mahabharata war lasted for 18 days [114]; hence, the organisation of the Gita is symbolic.

The Upanishads [110] translated by Eknath Easwaran provides a commentary and translation of the 11 major and 4 minor Upanishads. The 108 Upanishads [113] is a collection of the translation and commentary of all 108 Upanishads in a single book compiled by the Gita Society. The translation and commentary is done by a group of spiritual teachers who have tried to recover the Upanishads which have believed to be lost earlier; however, there are not much details about how they have recovered them [113]. The Chandogya Upanishad has highest number of words followed by the Katha Upanishad and the Brihadaranyaka Upanishad. The Ten Principal Upanishads [111] consists of the translation of the 10 major Upanishads. This text does not have a separate explanation for each Upanishad unlike the Upanishads by Eknath Easwaran. The Brihadaranyaka Upanishad consists of the highest number of words followed by the Chandogya Upanishad and Katha Upanishads. The Chandogya
Upanishad is one of the largest Upanishads consisting of 8 chapters which can be divided into 3 natural groups according to the philosophical ideas. The first group (Chapter 1 and Chapter 2) deals with the structure and different aspects of the languages and its expression, particularly with the syllable "Om" that is used to describe Brahman and beyond. The second group (Chapter 3-5) consists of the ideas of universe, life, mind and spirituality. The third group (Chapter 6-8) deals with the more metaphysical questions such as nature of reality and Self. Since first five chapters are intermixed with rituals, Shri Purohit Swami omitted them from in his translation along with some passages from the Brihadaranyaka Upanishad. Other authors also state that some of the passages of the Brihadaranyaka Upanishad has been omitted due to the repetitions. Brihadaranyaka Upanishad, consisting of 6 chapters discusses about different philosophical ideas including one of the earliest formulation of the Karma doctrine (Verse 4.4.5), ethical ideas such as self-restraint (Damah), charity (Danam) and compassion (Daya) and also other metaphysica topics related to philosophy of Advaita Vedanta. Eknath Easwaran translated this chapter as the Forest of Wisdom which starts with the one of Vedic theories of the creation of the Universe and then the dialogue between a great sage, Yajnavalkya, and his wife Maitreyi which is a deep spiritual discussion about death, possession, self, Brahman (God) and the Atman (Self). It contains one of the earliest psychological theories relating the human body, mind, ego and the Self. The Katha Upanishad is one of the legendary story of a small boy Nachiketa who met Yama (the god of Death) asks with him different questions about the nature of life, death, man, knowledge, Atman and Moksha (liberation). The Katha Upanishad consists of 2 chapters each consisting of 3 sections.

2.2 Framework

Our major goal is to map the topics in the Bhagavad Gita with Upanishads. We begin by selecting 12 prominent Upanishads (Isha, Katha, Kena, Prashna, Munda, Mandukya, Taittiri, Aitareya, Chandogya, Brihadaranyaka, Brahma, Svetasvatara) from the text translated by Eknath Easwaran. The major reason that we selected both by the same author for this task is to eliminate any bias in translation for topic modelling. However we also considered other translations as mentioned in the table and found that these bias does affect the similarity matrix. For example when we compared the similarity between the Upanishads by Eknath Easwaran and the Bhagavad Gita by the same authors, average similarity score is 3% better than that of the Bhagavad Gita by Eknath Easwaran and the Upanishads by Shri Purohit Swami. Finally, we also presents the visualization of the topics space of 108 Upanishads and its different part divided based on the original Vedas these Upanishads are originated from.

Next, we present a framework that employs different machine learning methods for topic modelling. Figure presents the complete framework for the analysis and topic modelling of the respective texts given in Table. In Figure the first stage consists of conversion of PDF files and text pre-processing as discussed in the previous section. In the second stage, we use two different sentence embedding models 1.) universal sentence encoder (USE) and 2.) Sentence-BERT(SBERT) for generating the word and documents embedding which is later passed thorough the topic extraction pipeline to generate the topic vector and finally we compared our results with the classical topic modelling algorithm LDA. Our framework to generate topics is similar to Top2Vec however we also used other clustering algorithms like K-Means. First, USE and SBERT are used to generate the joint semantic embeddings of documents and words. Since these embeddings are generally in higher dimension which is very sparse, we need to reduce the dimension of the embeddings to get the dense areas. We use dimensionality reduction techniques like UMAP and PCA for
reducing the high dimensional embedding vectors generated by the S-BERT and the USE. Next, we find dense clusters of topics in the document vectors of the corpus using clustering algorithms like HDBSCAN and K-Means. These clusters are represented by the centroid of document vectors in the original dimension, which is called as topic vectors. Next, we find top \(N(=50\) in our case) nearest words to the topic vectors which represent our final topic. Topic vectors also allows us to group the similar topics and hence reduce the number of topics using Hierarchical Topic Reduction.

Most of the topic modelling research involves the bench-marking model results on pre-existing datasets such as the 20 News Groups dataset, the Yahoo Answers dataset, Web Snippets dataset, W2E datasets. These datasets have been prepared to be used for the algorithms bench-marking tasks and consists of the fixed number of documents and words. The 20 News Groups Datasets for example consists of 15,465 documents and 4,159 words. Tweets have also been used for topic modelling tasks. Jonsson et al. for example, collected tweets from Twitter to prepare a datasets of 129,530 tweets and used LDA, Biterm-Topic-Model(BTM) and a variation of LDA algorithms for topic modelling to compare their performance. In case of Twitter based topic modelling datasets, a tweet is considered as Document, though Jonsson et al. aggregate documents to form pseudo-documents and found that it solves the poor performance of LDA on shorter documents. Murakami et al. used research papers published in the journal Global Environmental Change (GEC) from the first volume (1990/1991) to Volume 20 (2010) as the corpus for the topic modelling. They divided the a paper into several paragraph blocks and modelled them as a documents of the corpus.

Our dataset can be seen as similar to Murakani et al. The Bhagavad Gita and Upanishads are written in verse form and to maintain the originality of the texts, most of the translations also preserve the numbering of the verses. Other than the verses, the translations also contain commentary by the translator of the texts. While creating the datasets, we first created documents based on the verse number in the texts, i.e a verse
II-5(a). What winds up empirical life is (its) appearance as unreal. What discipline is required to know, this is a pot, except the adequacy of the means of right knowledge? Lord, have we not prophesied in thy name? and in thy name have cast out devils? and in thy name done many wonderful works?

Table 2. Processed text after removing special characters and transforming archaic words into modern English is considered as a document of the corpus, where the numbering are clearly mentioned. In other cases when verse numbers are not mentioned clearly, we considered one paragraph as one documents. In case of the commentary, we split the commentary into smaller parts to make them a document as done by Murakami et al. [126]. The statistics in terms of number of documents, number of words (# words), average number of words (avg # words), and number of verses (# verses) of different corpus (text files) and their details can be found in Table 3.

2.3 Text data extraction and processing

In order to process the files given in printable document format (PDF), we converted them into text files. Most of the PDF files were generated from the scanned images of the printed texts, hence we used optical character recognition (OCR) based open-source library[1]. This conversion from PDF to text file gave us a raw dataset consisting of all the texts shown in Table[1]. Next, pre-processing done on the entire datasets, which consists of the following steps.

1. Removing unicode characters generated in the text files due to noise in the PDF files;
2. Normalizing(assigning uniform verses from each text) verse numbering in the Upanishads and the Bhagavad Gita;
3. Replacing the archaic English words such as "thy" and "thou" with modern English words like your and you;
4. Removing the punctuation, extra spaces, and lower-casing;
5. Removing repetitive and redundant sentences such as "End of the Commentary".

Examples of selected text from the original document along with the processed text is shown in Table[2]. The original text and processed text has been given in the Github repository[2]. In topic modelling literature, word is the basic unit of data which is defined to be an items from vocabulary indexed by \{1,...,V\}, where V is the vocabulary size. A Document is a collection of N words represented by \( w = \{w_1, w_2, ..., w_N\} \), where \( w_i \) is the \( i^{th} \) word in the sequence. The corpus is considered as a collection of M documents denoted by \( D = \{w_1, w_2, ..., w_M\} \).[47]
### Technical details

In our framework, S-BERT and USE are used for the task of generating sentence embeddings. We used pre-trained S-BERT [3], which has been trained on a large multilingual corpus. The model uses DistilBERT [127] as the base transformer model, then its output is pooled using an average pooling layer and a fully connected (dense) layer is used finally to give a 512 dimensional output. We used different combination of dimensionality reduction techniques and clustering algorithms with the pre-trained semantic embeddings to get the final topics for each corpus.

The embedding dimension is reduced to the 5-dimension using the selected dimensionality reduction techniques i.e UMAP and PCA. UMAP uses two important parameters, n\_neighbors and min\_dist in order to control the local and global structure of the final projection. We fine-tuned these parameters to optimize the topic-coherence metric and use the final UMAP model with the default min\_dist value of 0.1, n\_neighbors value of 10 and the n\_components value of 5, which is the final dimension of the embeddings. We set the random-state to 42 and use cosine-similarity as the distance metric.

After getting the embedding of the documents in the reduced dimensions we used two different clustering algorithms - HDBSCAN [103,104] and K-Means [102] algorithms to cluster the documents where each clusters represent a topic. We fine-tuned different parameters of HDBSCAN to get the optimal value of topic coherence metric(Topic coherence is discussed with great details in next section), which represents how good our generated topics are. We chose the number of topics obtained at the optimal value of topic coherence metric as the optimal number of topics and used the same number as the value of K for K-Means Clustering algorithms. The min\_cluster\_size defines the smallest grouping size to be considered as cluster, we set it to 10. Finally, in the remaining two parameters, we use metric = euclidean and min\_samples = 5. The k-means algorithm is trained for the 300 iterations, with the num\_clusters parameters same as the number of labels found using HDBSCAN.

### Results

#### 3.1 Data Analysis

We begin by reporting key features of the selected texts (datasets) as shown in Table 3. The Upanishads by Eknath Easwaran contains 862 documents, 40737 words and 708 verses. Since this text contains explanation by the authors as well so the number of documents is more than the number of verses for this text. Ten Principal Upanishads by W.B. Yeats and Shri Purohit Swami Consists of 1267 documents and same number of verses as well. The corpus also consists of 27492 words with an average of 21.70 words per documents. The Bhagavad Gita by Eknath Easwaran consists of 700 verses and the same number of documents along with 20299 words with an average of 21.70 words per documents.

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https://huggingface.co/sentence-transformers/
Fig 2. Chapter Wise Word count for different texts in the dataset

(a) The Bhagavad Gita

(b) The Upanishads

(c) The Ten Principal Upanishads
Figure 2 shows the chapter-wise word count of the respective corpus. The Bhagavad Gita consists of 18 chapters and we see that Chapter 2 has the highest number of words, followed by Chapter 18 and Chapter 11. This is because these chapters contain relatively more number of verses and explain much deeper topics of Hindu philosophy. Chapter 18 of the Bhagavad Gita contains the highest number of verses (78) followed by the chapter 2 which contain 72 verses and chapter 11 containing 55 verses. Chapter 2 of the Bhagavad Gita discusses about the Samkhya and Yoga School of Hindu Philosophy. It teaches about the cosmic wisdom (Brahm Gyan) and the methods of its attainment along with the notion of qualia (Atman/self), duty, action (karma), selfless action (karma yoga), rebirth, afterlife, and the qualities of self-realized individuals (muni). Eknath Easwaran claimed this chapter as an overview for the remaining sixteen chapters of the Bhagavad Gita. Chapter 11 is also called as the "Vishwa Roopa Darshana Yoga" which has been translated as "The Cosmic Vision" by Eknath Easwaran, and "The Yoga of the Vision of the Universal" Form by Swami Chinmayananda. This chapter talks about the supreme vision of Lord Krishna which made Arjuna experience deep peace and joy of Samadhi (enlightenment) along with the feeling of being terrified at the same time. When terrified, Arjuna asks about the identity of the cosmic vision of God. Lord Krishna replies in verse-32 of Chapter 11 that came into Robert Oppenheimer’s mind when he saw the atomic bomb explode over Trinity in the summer of 1945. He mentioned, "A few people laughed, a few people cried. Most people were silent. I remembered the line from the Hindu scripture, the Bhagavad Gita; Vishnu is trying to persuade the Prince that he should do his duty and, to impress him, takes on his multi-armed form and says, Now I am become Death, the destroyer of worlds."

The n-gram is typically used to provide basic statistics of a text using a continuous sequence of words or other elements. Bi-grams and tri-grams are typical examples of n-grams. Figure 4 shows the count of top 10 bigrams and trigrams along with the top 20 words for the Upanishads by Eknath Easwaran. In the case of the Upanishads by Eknath Easwaran, (lord, love) is the most frequent bigram which has occurred more than 60 times followed by (realize, self) and (go, beyond). In the same corpus, when we look at the trigram’s bar plot we find that (united, lord, love), (self, indeed, self) and (inmost, self, truth) to be the top 3 trigrams of the corpus. Similarly, Figure 5 shows unigrams, bigrams and the trigrams of the Ten Principal Upanishads. Although these n-grams just state the frequency of occurrence of the continuous sequence of words, they give a rough idea about the themes and topics discussed in the corpus. This can be seen in Figure 13 that a lot of topics do contain these words. We can see that 'self' is one of the predominant word of topic 4 and topic 8 of the ten principal Upanishads. In fact when we observe these topics carefully, we find that the entire topic is related to the theme of 'self'. Similarly, we find words 'lords', 'god' and 'sage' to be the predominant words in topic 1 and topic 3 of the ten Principal Upanishads. Figure 3 shows the bigrams, trigrams and word count for the Bhagavad Gita. We see that 'arjuna', 'self', 'krishna', 'action' and 'mind' are the top 5 words of the Bhagavad Gita. Among the bigrams and trigrams, we see that (every, creature), (supreme, goal) and (selfless, service) are top 3 bigrams while (attain, supreme, goal), (beginning, middle, end) and (dwell, every, creature) are the top 3 trigrams of the text. Since Arjuna and Krishna are the protagonists of the text, it is obvious for them to be among the top words of the text. We see that other than these, 'self, action, and mind' are the prominent words that give us a basic idea about the themes that can be verified from the topics presented in Figure 12. Topic 1 of the Bhagavad Gita shown in Figure 12 shows all the names of the Hindu spiritual entities (deities). We find that Krishna and Arjuna are one of the major one among them. This topic also includes other entities and deities such as Jayadratha, Vishnu and Bhishma that have been mentioned by the
Lord Krishna in the text. The words related to the ‘self’ can be seen in topic 2 of Figure 12; hence, we can conclude that themes related to self are present in Topic 2 identified by our framework. We can also see that topic 13 of the Bhagavad Gita contains the words related to ‘action’ (karma) which is also one of the top 5 words of the texts.

In terms of the individual word frequency, we find that "self" is one of the most occurred word in all the three corpus which is a major theme of Hindu Philosophy. The "self" is the translation from the Sanskrit word "Atman", which refers to the spirit, and more precisely "qualia" as known in the definition pertaining to the hard problem of consciousness [132]. The "Atman" is also often translated as consciousness and there are schools of thought (Advaita Vedanta [133]) that sees the Atman as Brahman (loosely translated to the concept of God or super-consciousness) [4,134]. Often, it is wrongly translated to the term soul which is an Abrahamic religious concept, where humans only to have the soul and the rest of life forms do not. Atman, on the other hand, is the core entities of all life forms and also of non-life forms in Hindu philosophy. Not only in Upanishads but it has been explained in The Bhagavad Gita as well with a great details. Finally, "attain supreme goal" is the most occurred trigram of the Bhagavad Gita which suggests that the Bhagavad Gita talks about attaining supreme goal with a great details along with the other philosophical topics. The Bhagavad Gita is also known as the Karma Upanishad or the text that focuses on philosophy of karma (action/work) [8]. The major focus of the Bhagavad Gita is karma philosophy given a conflicting situation and the path to self realisation as the goal of life, and hence, it has also been recognised as a book of leadership and management [136,137], and psychology [138].

Fig 3. Visualisation of top 20 words, and top 10 bigrams and trigrams for the Bhagavad Gita.

3.2 Modelling and Predictions

3.2.1 Topic Coherence

Quantitative evaluation of the topic model is one of its major challenge. Initially, topic models were evaluated with held-out-perplexity but it does not correlate with the human evaluation [139]. A topic can be said to be coherent if all or most of the words of the topic support each other or are related [140]. Human evaluation of topic coherence is done in two ways: 1.) rating, where human evaluators rate the topic quality on a three point topic quality score, and 2.) intrusion, where each topic is represented by its top words along with an intruding word which has very low probability of belonging to the topic since it does not belong in the topics uncovered. It is a behavioral way to judge topic coherence and measured by how well a human evaluator can detect the
Fig 4. Visualisation of top 20 words, and top 10 bigrams and trigrams for the Bhagavad Gita. Upanishads by Eknath Easwaran.

Fig 5. Visualisation of top 20 words, and top 10 bigram and trigrams for the ten principal Upanishads.
intruding word. Automated topic coherence metric based on normalized pointwise mutual information (NPMI) correlates really well with the human evaluation and interpretation of the topic coherence. Röder et. al. provided a detailed study on the coherence measure and its correlation with the human topic evaluation data. We use the topic coherence NPMI measure (TC-NPMI) as a metric to fine tune and evaluate different models on different corpus. Equation 4 gives the NPMI for a pair of words ($w_i$, $w_j$) from the top N (set to 50) words of a given topic:

$$\text{NPMI} (w_i, w_j) = \frac{\log \left( \frac{P(w_i, w_j) + \epsilon}{P(w_i) P(w_j)} \right)}{- \log \left( P(w_i, w_j) + \epsilon \right)}$$

(4)

where, the joint probability $P(w_i, w_j)$, i.e the probability of the single word $P(w_i)$ is calculated by the Boolean sliding window approach (window length of $s$ set to the default value of 110). A virtual document is created and the count of occurrence of the word ($w_i$) or the word pairs ($w_i$, $w_j$), and then it is divided by the total number of the virtual documents.

We use TC-NPMI as the topic-coherence measure to evaluate different topic models and tune different hyper-parameters of different algorithms. Table 4 shows the value of metric for different model on different datasets. We trained the LDA model for 200 iterations with other hyper-parameters set to the default value as given in the gensim library. We fine-tuned the number of topics parameters to get the optimal value of TC-NPMI.

Next, we evaluate different components in the BERT-based topic model presented earlier (Figure 1 from where we have five major approaches: 1.) SBERT-UMAP-HDBSCAN, 2.) SBERT-UMAP-KMeans, 3.) USE-UMAP-HDBSCAN, 4.) USE-UMAP-KMeans, and 5.) LDA. In Table 4, we observe that in the case of the Bhagavad Gita, the combination of USE-UMAP-KMeans gives the best TC-NPMI score on both the datasets with a very slight difference when compared to USE-UMAP-HDBSCAN and SBERT-UMAP-KMeans. Note that high TC-NPMI results indicate better results. In the case of the Upanishads, we find a similar trend. We also observe that LDA does not perform well, even after fine-tuning the number of topics parameters to optimize the topic coherence.

Although the use of KMeans for the clustering component gives the best result, we choose USE-UMAP-HDBSCAN to find the topic similarity between the Upanishads and The Bhagavad Gita in the next section. This is because HDBSCAN does not require us to specify the number of clusters, that corresponds to the number of topics, beforehand. USE-UMAP-HDBSCAN gave 18 topics for the corpus - the Upanishads for the optimal value of the topic coherence mentioned in Table 4. Similarly, we got 14 topics from the Bhagavad Gita. In the case of the 108 Upanishads which contains larger number of documents as compared to the rest of the texts, we got more topics for the optimal values of topic coherence. However, we reduced the number of topics using hierarchical topic reduction in some of cases for example, while comparing the topic similarity of the Bhagavad Gita and the Upanishads. Since the number of documents and words are different for different corpus as seen from Table 3, the number of topics obtained are different for different corpus. For example, in the Ten Principal Upanishads – there are 1267 documents and we got 28 topics for them at the optimal value of topic coherence. Similarly for 108 Upanishads, there are 6191 documents which gives 115 topics. Also, while plotting the semantic space for the different topics obtained by our model as shown in Figure, we reduced the number of topics to 10 in order to visualize the topic’s semantic space clearly.
### 3.2.2 Topic similarity between the Bhagavad Gita and the Upanishads

There are studies that suggest that the Bhagavad Gita summarizes the key themes of the Upanishads and various other Hindu texts [148–150]. The Bhagavad Gita along with the Upanishads and the Brahma Sutras is known as the Prasthanatrayi [151–155], literally meaning the three points of departure [151], or the three sources [153] which makes the three foundational texts of the Vedanta school of Hindu philosophy [13,14,149,150,156]. Sargeant et al. [148] stated that the Bhagavad Gita is the summation of the Vedanta. Nicholson et al. [150] and Singh et al. [149] regarded the Bhagavad Gita to be the key text of Vedanta.

Another source which discusses a direct relationship between the Bhagavad Gita and the Upanishads is the Gita Dhyanam (also sometimes called Gita Dhyana and Dhyana Slokas) which refers to the invocation of the Bhagavad Gita [147, 157, 158]. We need to note that Gita Dhyanam is an accompanying text with 9 verses used for prayer and meditation that complements the Bhagavad Gita. These 9 verses are attributed traditionally to Sri Madhusudana Sarasvati and are generally chanted by the students of Gita before they start their daily studies [157]. These verses offer salutations to various Hindu entities such as the Vyasa, Lord Krishna, Lord Varuna, Lord Indra, Lord Rudra and the Lord of the Maruta and also characterises the relationship between the Bhagavad Gita and the Upanishads. The 4th verse of the Gita Dhyanam states a direct cow and milk relationship between the Upanishads and the Gita. Eknath Easwaran [147] translated the 4th verse as "The Upanishads are the cows milked by Gopala, the son of Nanda, and Arjuna is the calf. Wise and pure men drink the milk, the supreme, immortal nectar of the Gita". Although these relationships have been studied and retold for centuries, there are no existing studies that establishes a quantitative measure to this relationship using modern language models. Next, we evaluate and discuss similar relationships both quantitatively using a mathematical formulation and also qualitatively by looking at the topics generated by our models as shown in Tables 5, 6, and Figures 12, 13.

In order to evaluate the relationship between the Bhagavad Gita and the Upanishads, we used the obtained topics to find a similarity matrix as shown in the heatmap of Figure 6. The vertical axis of the heatmap shows the topics of the Bhagavad Gita while the horizontal axis of the heatmap represent the topics of the Upanishads. The heatmap represents the cosine similarity of the topic-vector obtained by the topic model. Therefore, in each of the topics obtained from the Bhagavad Gita, we calculate its similarity with all the topics of the Upanishads and then find the topic with maximum similarity. This operation can be mathematically represented by the Equation 5a. We represent the number of topics in Gita by $N_{gita}$ and the number of topics in Upanishads by $N_{upan}$. In each topic $T^g_{gita}$ from the Bhagavad Gita, we explore and find the most similar topic from Upanishads $T^g_{upan}$. The topics and their similarity score can be found in Table 5 and Table 6. We observe a very high similarity in the topics of the Bhagavad Gita and two different texts of Upanishads (shown in Table 5).
These tables also show the mean similarity score which is given by the average of all the similarity scores as shown in Equation 5b and given below:

$$T_{i_{\text{upan}}} = \arg \max_{j=1}^{N_{\text{upan}}} \text{Sim}(V_{gita}^i, V_{upan}^j)$$

$$\text{AvgSim} = \frac{\sum_{i=1}^{N_{\text{gita}}} \max_{j=1}^{N_{\text{upan}}} \text{Sim}(V_{gita}^i, V_{upan}^j)}{N_{\text{gita}}}$$

where $V_{gita}^i$ and $V_{upan}^i$ represent the $i^{th}$ topic vectors of the Bhagavad Gita and the Upanishads, respectively. $\text{Sim}(.,.)$ represent the similarity measure defined by equation 6, which is cosine similarity in our case. There are various other measures of similarity score between two vectors; however, the cosine similarity is used widely in the literature [159–161]. One of the major reason for this is its interpretability. Value of cosine similarity between any two vector lies between 0 and 1. A value closer to 1 represent that vectors are almost similar to each other and a value closer to 0 represent that they are completely dissimilar.

The cosine similarity between any two vectors $U$ and $V$ is represented by Equation 6.

$$\text{Sim}(U, V) = \cos(\theta) = \frac{U \cdot V}{\|U\|\|V\|}$$

We can observe from the Table 5 that a number of the topics of Bhagavad Gita are similar to the topics of the Upanishads with more than 70% similarity. We also find that topic 4 of the Bhagavad Gita is similar to that of the topic 5 of the Upanishads (Eknath Easwaran) with a similarity of 90%. We can see that both of these topics contains almost similar words. Similarly, topic-5 of the Bhagavad Gita has a similarity of 86% when compared with topic 8 of the Upanishads. Both of these topics are are related to immortality and death. The similarity can be observed via Table 5 for example, topic-1 of both Bhagavad Gita and the Upanishads (Eknath Easwaran) consists of the words related to Hindu deities and entities such as Krishna, Arjuna, Vishnu and Samashrava, they also have a similarity of 76%.

Figure 8 represents a visualization of the semantic space of the Bhagavad Gita and the Upanishads with given topic labels. Although we find in Table 4 that Bhagavad Gita and the Upanishads gave 14 and 18 topics respectively, we are only presenting 10 topics from both of these texts in order to have a clear visualization. Each dots in the diagram represent the two dimensional (2D) embedding of each of the documents of the corpus. These topics can be seen in Figure 12 along with some of the most relevant documents of the text with their source. Figure 12 represents the themes related to the deities and the entities of the Hindu philosophy. We can also observe that documents relevant to topic-1 have been originated form chapter 1, 3 and 10. These all are the verses containing the name of the Hindu deities. Topic-2 of the same table encapsulate the idea of self, worship, desire and fulfillment. A similar pattern can be observed in Table 6 which represent the topics and documents of the Ten Principal Upanishads [111].

### 3.2.3 108 Upanishads

Finally, we apply a selected respective topic modelling approach (USE-UMAP-HDBSCAN) from our topic modelling framework (Figure 1) for analysis of the complete 108 Upanishads. We note that the 108 Upanishads are also known as
**Fig 6.** Heatmap showing the similarity between different topics of Bhagavad Gita and Upanishads generated from a selected approach (SBERT-UMAP-HDBSCAN).

### Table 5. Topics of the Bhagavad Gita (Eknath Easwaran) with most similar topics from the Upanishads (Eknath Easwaran)

| Topics of Gita | Gita Topic ID | Most Similar topics in Upanishads | Upanishads Topic ID | Similarity Score |
|---------------|--------------|----------------------------------|---------------------|------------------|
| arjuna,ikshvaku,sankhya,ashvatha,kusa,vishnu | topic-2 | desires, happiness, eternal, selfless, beings, spiritual, existence, spirituality, desire, joy, eternity, buddhism | topic-11 | 0.76 |
| sages, wise, devotees, sages, vishnu, mahabharata | topic-1 | sage, wisdom, devotee, sages, vishnu, mahabharata, devotees, samashrava, hindu, mahavakyas, theravada | topic-1 | 0.76 |
| brahman, wisdom, devotees, brahma, devotee, teachings, sages, worship, divine, devote | topic-7 | sage, wisdom, devotee, sages, vishnu, mahabharata, devotees, samashrava, hindu, mahavakyas, theravada, hindus, buddhi | topic-1 | 0.74 |
| existence, universe, beings, eternal, nonexistence, immortality, creatures, eternity, creature, cosmos | topic-8 | universe, omnipotent, eternal, cosmos, eternity, beings, cosmic, immortal, gods, celestial, death, beyondness, god, heavens | topic-7 | 0.73 |
| meditation, meditate, spiritually, spiritual, yoga, minds, asceticism, spirit, nirvana, wisdom | topic-4 | meditation, meditating, meditates, meditate, meditation, minds, mind, spiritually, interiorize, enlightenment, spiritual | topic-5 | 0.90 |
| immortality, death, mortality, immortal, deathless, eternity, eternal, dying, mortal, dead, mortals | topic-5 | immortality, death, immortal, mortality, deathless, mortal, dying, mortals, eternity, deathlessness, eternal | topic-6 | 0.86 |
| gods, eternal, universe, beings, eternity, heavens, celestial, immortality, heavenly, divine, god | topic-6 | celestial, sun, heavens, earth, earthly, heaven, heavenly, luminous, sunrise, sky, universe, illumined, light, illumine | topic-8 | 0.80 |
| ignorance, ignorant, wisdom, delusion, darkness, delusion, evils, intellects, eternal, asceticism | topic-9 | meditation, meditating, meditates, meditate, meditated, minds, mind, spiritually, interiorize, enlightenment, spiritual | topic-5 | 0.67 |
| senses, sense, feeling, selflessly, selflessly, selfishly, feel, selfish, minds, oneself, themselves, perceive | topic-10 | meditation, meditating, meditates, meditate, meditated, minds, mind, spiritually, interiorize, enlightenment, spiritual | topic-5 | 0.78 |
| enemy, enemies, conquer, defeat, light, fighting, conquered, battle, fought, nonviolence, dishonor | topic-11 | immortality, death, immortal, mortality, deathless, mortal, dying, mortals, eternity, deathlessness, eternal, dead, deaths | topic-6 | 0.60 |
| forgiving, renunciation, fulfill, selfless, nonbeing, unpleasant, selflessly, fulfilling, insatiable, indulging | topic-12 | selfs, self, selfless, oneself, himself, themselves, selfish, ego, itself, egoism, yourself, independently, ourselves, autonomic | topic-14 | 0.55 |
| actions, act, actions, acting, inaction, selflessly, selfless, themselves, unaffected, indifference, ignorance | topic-13 | selfs, self, selfless, oneself, himself, themselves, selfish, ego, itself, egoism, yourself, independently, ourselves, autonomic | topic-14 | 0.60 |
| beings, spiritual, gods, divine, heavens, ocean, spiritually, shudra, ahamsara, rudras, sacred, worship | topic-14 | sage, wisdom, devotee, sages, vishnu, mahabharata, devotees, samashrava, hindu, mahavakyas, theravada, hindus, buddhi | topic-1 | 0.68 |

**Mean Similarity Score (AvgSim): 0.73**
Fig 7. Heatmap showing the similarity between different topics of Bhagavad Gita (Eknath Easwaran) and the Ten Principal Upanishads (Shri Purohit Swami) generated from a selected approach (SBERT-UMAP-HDBSCAN).
Fig 8. Visualization of the semantic space of The Bhagavad Gita and The Upanishads with topic labels.
Fig 9. Visualization of the Combined Semantic Space of The Bhagavad Gita and The Upanishads (PCA and UMAP).

(a) UMAP Embeddings

(b) PCA Embeddings
Vedas # Upanishads

| Vedas          | # Upanishads |
|----------------|-------------|
| Atharva-Veda   | 31          |
| Krishna-Yajur-Veda | 32        |
| Sukla-Yajur-Veda | 19         |
| Sama Veda      | 16          |
| Rig Veda       | 10          |

Table 6. Topics of the Bhagavad Gita (Eknath Easwaran) with most similar topics from the Ten Principal Upanishads (Shri Purohit Swami & W.B. Yeats)

Table 7. Classification of Upanishads based on original Vedas it is derived from

Upashads that fall under 4 different categories identified by the four Vedas (Rig Veda, Sama Veda, Yajur Veda, Artha Veda) which are known as the founding texts of Hinduism. The Rig Veda is the oldest Hindu texts written in ancient Sanskrit and believed to be remembered orally from guru-student tradition of mantra-recital. It has been translated and understood to have a significant role in the development of various aspects of the Vedas since it has been passed down through generations.

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written in ancient Sanskrit in verse with symbolism \cite{163}. The Upanishads are known as the texts that explain the philosophy of the Vedas and also known as the concluding chapters that have been added to the four Vedas \cite{164}. Table \ref{tab:7} gives information about how the 108 Upanishads have been grouped according to their historical relevance to the respective Vedas.

Figure \ref{fig:11} presents visualization of the semantic space of different parts (divided by 4 Vedas as shown in Table \ref{tab:7}) of 108 Upanishads.

4 Discussion

The high level of semantic and topic similarity between the Bhagavad Gita and the different sets of the Upanishads by the respective authors is not surprising. It verifies well known thematic similarities as pointed out by Hindu scholars such as Swami Vivekananda \cite{165} and western scholars \cite{14}. Bhagavad Gita is well known as the central text of Hinduism that summaries the rest of the Vedic corpus. The Bhagavad Gita is a conversation between Lord Krishna and Arjuna in a situation where Arjuna has to go to war. The Bhagavad Gita is a chapter from the Mahabharata that uses a conflicting event to summarize philosophy of the Upanishads and the Vedic corpus. The Mahabharata is one of the oldest and longest texts written in verse form in Sanskrit which describes a historical event (118,087 sentences, 2,858,609 words) \cite{166}. We note that most of Hindu ancient texts have been written in verse so that it can be sung and remembered through an oral tradition in an absence of a writing system.

The goal of Lord Krishna was to motivate Arjuna to do his duty (karma) and go to war to protect ethical standards (dharma) in the society. Krishna, in the Bhagavad Gita begins by renouncing his duties as a warrior. We note that the Mahabharata war, is believed to take place after the Vedas and the Upanishads were composed. Note that by composition, it does not mean that these texts were written, they were sung and verses became key mantras that were remembered through a guru-student tradition for thousands of years. There are accounts where the Vedas have been mentioned in the Mahabharata. Hence, Krishna is known as a student of the Vedic corpus which also
Fig 11. Visualization of the semantic space of different parts (based on 4 Vedas) of 108 Upanishads.
refers to the entire library of Hindu science, literature, history and philosophy. Therefore, the topics in the Upanishads were well known by Lord Krishna and he may have merely used some of the themes to highlight about themes of duty, ethics (dharma) and work (karma) in order to motivate Arjuna to do his duty at the time of need, otherwise, his side (Pandava) would lose the war to the opposition (Kaurava). The Mahabharata war has blood relives on opposing sides of the war battleground known as Kurushetra and hence it was difficult for Arjuna to make a decision either to fight for dharma or renounce his duties and become a yogi (mystic).

Table 5 further compares the topics of the Bhagavad Gita with the Upanishads. We can observe that each of the topic encapsulate some of the ideas expressed in selected verses shown in Tables 7 and 8. If a topic of the Gita and the Upanishads have very high similarity, this represents the fact that the ideas encapsulated by the topics of the Gita and the Upanishads are almost same. In Table 5, we can observe that topic 4 of the Bhagavad Gita and topic-5 of the Upanishads have a similarity of 90%, this can be seen from the topics also they are representing the similar themes that are related to the ideas of meditation, yoga and spirituality. Similarly, we observe that topic-5 of Gita have a similarity score of 86% when compared with topic-6 of the Upanishads. Here, we can also observe that both topics encapsulate similar ideas of death, mortality and immortality. Similar ideas can be observed in Table 6 as well the topics of the Bhagavad Gita is compared with the topics of the Upanishads.

Figure 8 depicts a representation of the semantic space of the Bhagavad Gita and the Upanishads with topic labels. It represents the lower dimensional embedding of the very high dimensional document vectors. In Figure 8, we represented only 10 topics in order to retain the clarity of the diagram. Figure 9 shows the UMAP and PCA embedding of the entire document. In order to generate this plot, we first created the embeddings of each documents and then reduced the embedding to 2D by using PCA and UMAP. After reducing the dimension, we assigned the labels (Gita, and the Upanishads) based on the corpus. Figure 9 shows that low-dimensional embeddings reveals very clear overlaps across the documents.

Even with the presence of translation bias by considering two different translations of the Upanishads, our results demonstrate a very high resemblance between the topics of these two texts, with a mean cosine similarity of more than 70% between the topics of the Bhagavad Gita and those of the Ten Principal Upanishads by Shi Purushit Swami and W.B Yeats. Eight of the fourteen topics extracted from the Bhagavad Gita have a cosine similarity of more than 70% with the topics in the 10 Principal Upanishads, which can also be seen in the table and 3 of them have a similarity of more than 80%. When considering the translation of both texts by same author as in the case of the Bhagavad Gita and the Upanishads, we see that average similarity increase to 73% with 9 out of 14 topics having more than 70% similarity and 3 of them having a similarity of more than 80%. We also found that topics generated by the BERT based models show very high coherence as compared to that of the LDA. Our best performing model gives a coherence score of 73% on The Bhagavad Gita, 69% on The Upanishads, 73% on The ten Principal Upanishads and 66% on the 108 Upanishads.

The major limitation is due to the translation bias, which is not present when we take the same translator - this is why we chose the Upanishads and Bhagavad Gita by Eknath Easwaren in order to limit the bias. However, if we consider the complete 108 Upanishads, such translation bias remain. Moreover, the style and language of the translations not only depend on the translator but on the era. In the case of the 108 Upanishads, a group of translators have contributed which creates further biases. However, in terms of topics uncovered, we find a consistent set of topics that well alight with the respective texts, after manually verifying it.

Further extension can be done by taking the other translations into consideration.

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The Ten Principal Upanishads [111] published in 1938, was translated by the Irish poet William Butler Yeats and Hindu guru Shri Purohit Swami. The translation process occurred between the two authors throughout the 1930s and this book can has been claimed as one of the final works of William Butler Yeats [167]. We note that Shri Purohit Swami has also translated the Bhagavad Gita, hence this would be a good companion with Eknath Eashwaren for the respective texts. These extensions could help in refining the proposed framework.

Moreover, in terms of the mythological texts and epics, there are various texts such as the Vishnu Purana, Shiv Purana out of the 18 different Puranas that have underlying topics that are similar. In this study, we focused on philosophical texts, while in future studies, there can be scope for topic modelling from selected texts in the Puranas. The framework can also be used to study texts from other religions, along with non-religious and non-philosophical texts. Furthermore, it can be used to study themes of modern poetry, writers, songs and be used to compare different religions and time frames, i.e how the themes changes over different centuries, prior to or after a war or a pandemic (such as the COVID-19).

We note that there exists specialised BERT pre-trained models such as those for medicine and law [168–173], but there is nothing yet developed for philosophy. Hindu philosophy is distinct and has terms and ideas that are not present in other philosophical areas (such as western philosophy). Hence, we need specialised pre-trained BERT model for Hindu philosophy which can provide better predictions in related language tasks since it will have better knowledge-base. This work can further be improved using language models for the native Sanskrit text. We intend to explore topic models after building BERT-like language models for Indian philosophical literature written in Sanskrit.

We note that our previous work focused on semantic and sentiment analysis of the Bhagavad Gita translations [174]. Augmenting semantic and sentiment analysis to our proposed topic modelling framework can provide more insights to the meaning behind the philosophical verses. We plan to build our models in a similar fashion and investigate their variations for texts in three different languages: Hindi, English, and Sanskrit. Finally, post verification study is needed where Sanskrit expert and Hindu philosophers can study the topics uncovered by the proposed framework.

The Bhagavad Gita and the Upanishads are considerably large texts in the content of religious and philosophical texts. However, the proposed framework can be used for larger corpus such as modelling overlapping topics around the Mahabharata and the Puranas, which are texts that are magnitudes larger than the ones considered in this study. However, we note that the Bhagavad Gita and Upanishads, although smaller in size are more condensed in philosophy while the Mahabharata is an epic poem.

In future work, there can be a detailed study of the topics uncovered with a discussion of related texts in Vedic studies that relate to morphology, lexicography, grammar (patterns in sentences), meter (lengthy sentences), and phonology (sound system), etc. Furthermore, we need to create processed benchmark text datasets for Indian languages that can benefit NLP applications associated with Indian languages.

5 Conclusion and Future work

We presented a topic modeling framework for Hindu philosophy using state-of-art deep-learning based models. The use of such technique for studying Hindu texts is relatively novel; however, computational and statistical approaches have been used in the past. The major goal of the study was to link the topics from the Upanishads with the Bhagavad Gita.

The representation of the low-dimensional embeddings presented in this work reveals
a lot of overlap between the Upanishads and the Bhagavad Gita's topics, which adds to our objective of demonstrating the Bhagavad Gita's relationship with the Upanishads. Given the importance of religious literature to a community, employing computational models to verify any of its old and traditional philosophical principles demonstrates the scientific nature of the literature and religion. Despite the fact that the idea of the Gita being the essential extract of the Upanishads has been written and researched in ancient Indian philosophical literature for generations, no attempt has ever been made to substantiate this facts using computational and scientific methodologies. Our research presents a novel way for applying modern deep learning-based methods to a centuries-old philosophical narratives.

Data and Code

Python-based open source code and data can be found here.

Author contributions statement

R. Chandra devised the project with the main conceptual ideas and contributed to overall writing, literature review and discussion of results. M. Ranjan provided implementation and experimentation and further contributed in results visualisation and analysis along with writing.

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Appendix

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| Topics of Gita | Gita Topic ID | Relevant documents with each of the topics | Sense No |
|---------------|--------------|------------------------------------------|----------|
| krishna, yadu... | topic-1 | 1. SANAYA: This is Arjuna, the great warrior, who spoke to Sri Krishna. With the words, O Krishna, I will not fight, he fell silent. 2. SANAYA: This is how Arjuna, the great warrior, spoke to Sri Krishna. With the words, O Krishna, I will not fight, he fell silent. 3. Among the Vrishnis I am Krishna, and among the Pandavas I am Arjuna. Among sages I am Vyasa, and among poets, Upanishad. | (1.24) (2.9) (10.37) |
| self, selff... | topic-2 | 1. Not delayed by pride, free from selfish attachment and selfish desire, beyond the duality of pleasure and pain, ever aware of the Self, if we go forward to that eternal goal. 2. That devotee who looks upon friend and foe with equal regard, who is not beset by praise or blame never cast down by blame, alike in heat and cold, peace and pain, free from selfish attachments. 3. Free from self-will, aggressiveness, arrogance, and the lust to possess or事物, they are at peace with themselves and others and enter into the unitative state. | (1.55) (1.58) (18.53) |
| worship, dharma... | topic-3 | 1. With their senses subdued and mind serene and striving for the good of all beings, they too will very come unto us. 2. But they who for whom I am the supreme god, who do all work renouncing self for me and meditate on me with single-hearted devotion. 3. Those who see in me that Supreme Self truly. They have found the source of all wisdom, Arjuna, and they worship me with all their heart. | (12.4) (12.6) (15.19) |
| meditation, meditation... | topic-4 | 1. The practice of meditation frees one from all affliction. This is the path of yoga. Follow it with determination and sustained enthusiasm. 2. Those who aspire to the state of yoga should seek the Self in inner solitude through meditation. With body and mind controlled they should constantly practice one-pointedness, free from expectations and attachment to material possessions. | (6.25) (6.12) |
| immortality, death... | topic-5 | 1. Going beyond the three gunas which form the body, they leave behind the cycle of birth and death, deprivation and sorrow, and attain immortality. 2. Those who rely on this wisdom will be united. For there is neither rebirth nor fear of death. 3. As the same person inhabits the body through childhood, youth, and old age, so too at the time of death he attains another body. The wise are not delayed by these changes. | (14.29) (14.42) (21.13) |
| god, god... | topic-6 | 1. AUKUNA: O Lord, I see within your body all the gods and every kind of living creature. I see the Creator, the Lord, seated on a lotus. I see the ancient sages and the celestial serpents. 2. I see infinite mouths and arms, stomachs and eyes, and you are embodied in every form. I see you everywhere, without beginning, middle, or end. You are the Lord of all, and an atom is the bliss of you. 3. You light up the world through your burning mouths and swallow them. Filled with your terrible radiance, O Vishnu, the whole of creation burns into flames. | (11.15) (11.16) (11.30) |
| brahman, wisdom... | topic-7 | 1. Listen and I shall explain now, Arjuna, how one who has attained perfection also attains Brahmam, the supreme consummation of wisdom. 2. Approach such a person to realize the purpose of life and question them with reverence and devotion, they will instruct you in this wisdom. 3. Heed of their sins and conflicts, working for the good of all beings, the holy sages attain nirvana in Brahmam. | (18.50) (43.4) (52.5) |
| existence, existence... | topic-8 | 1. I pervade the entire universe in my unmanifested form. All creatures find their existence in me, but I am not limited by them. 2. My own being is unchanging and I am the Lord who dwells in every creature. Through the power of my own Maya, I manifest myself in a finite form. 3. I am the true Self in the heart of every creature, Arjuna, and the beginning, middle, and end of their existence. | (9.4) (4.6) (10.29) |
| ignorance, ignorance... | topic-9 | 1. Out of compassion I destroy the darkness of their ignorance. From within them I light the lamp of wisdom and dispel all darkness from their lives. 2. I am the savior who extinguishes all, and the art of statelessness in those who lead. I am the silence of the unknown and the wisdom of the wise. 3. But ignorance is destruction by knowledge of the Self within. The light of this knowledge shines like the sun, revealing the supreme Brahmam. | (10.11) (10.38) (5.16) |
| senses, senses... | topic-10 | 1. Renouncing their selfish attachments, those who follow the path of service work with body, senses, and mind for the sake of self purification. 2. Some renounce all enjoyment of the senses, sacrificing them in the fire of self restraint. Others partake of some sense objects but refrain in service through the fire of the senses. 3. Using the mind, ears, eyes, nose, and the senses of taste and touch, the Self enjoys sense objects. | (5.11) (4.29) (15.9) |
| forgiving, renunciation... | topic-11 | 1. It does not become you to yield to this weakness. Arise with a brave heart and destroy the enemy. 2. But if you do not participate in this battle against evil, you will incur sin, violating your dollars and harm. 3. Having made yourself alike in pain and pleasure, profit and loss, victory and defeat, engage in this great battle and you will be freed from sin. | (2.23) (2.23) (2.23) |
| being... | topic-12 | 1. As long as one has a body, one cannot renounce action altogether. True renunciation is giving up all desire for personal reward. 2. It is better to perform one's duties imperfectly than to shirk the duties of another. By fulfilling the obligations he is born with, a person never comes to grief. 3. Those who are delayed by the operation of the gunas become attached to the results of their action. Those who understand these truths might not unsettle the ignorant. 4. They remain impartial, undisturbed by the actions of the gunas. Knowing it is that which acts, they abide within themselves and do not vacillate. 5. Actions do not cling to me because I am not attached to their results. Those who understand this and practice it live in freedom. | (18.18) (18.47) (3.29) (14.23) (14.41) |
| being, spiritual... | topic-13 | 1. Among purifying forces I am the wind among warriors zara of water currents I am the crocodile, and of rivers I am the | (10.31) |
| 1. I am the cosmic serpents and save the god of the universe who is the noble ancestor among the noble ancestors among the forces which restrain I am the god of | (10.29) |
| 3. Among the nadas I am Shankara among the spirits of the natural world I am kubera god of wealth | (10.23) |
| Topic Words | Topic ID | Relevant Documents of the Topic | Source of the document |
|-------------|----------|---------------------------------|------------------------|
| heavenborn, eternal, heavens, celestial, heaven, fire, heavenly, spirits, gods, almighty, immortality, being, burning, spirit, immortal, divine, flame, soul, spiritual, godliness, everlasting, gods, souls, blaze, fames, earthly immortality, but spirit, fires, somewhere, mortal, godly, worship, worship, words, earth, worship, lighting, sun, worship, enlightened, devotion, fire, godly, sacred, death, sacrifice, devotion, enlightened, godness | 1. | 1. Gautama! Heaven is the sacrificial fire, sun its fuel, rays its smoke, day its flame, quarters its coal, sub quarters its sparks. Gods offer faith as an oblation and create king moon. | Bhedaibaranaya Book VIII |
| | 2. | World is the sacrificial fire, earth its fuel, fire its smoke, night its flame, moon its coal, stars its sparks. Gods offer fire as an oblation and create food. | Bhedaibaranaya Book VIII |
| | 3. | Wind and sky are immeasurable, immortal, unstable, ungovernable; they come from the un grappling, from God that shines through the sun, the substance of the ungovernable. | Bhedaibaranaya Book III |
| sage, vaidyam, jayalil, sages, told, riddle, heard, spirit, spoke, speaks, spirit, understood, wisdom, wise, wisdom, saying, shokuma, said, bhokuma, siva, devote, know, obey, palanjan, mark, heard, many, understanding, words, speaking, hirayana, hearer, scholars, migrant, asked, say, preached, what, tell, proclaims, shawsh, wondered, king, obey | Topic-2 | 1. Bhusha meditation and found that life is Spirit. From life all things are born, by life they live, can set life they move, in life they return. Having found this he said to his father: Lord! Tell me more about Spirit. | Taittireeya Book III |
| | 2. | Mystery said: What can I do with that which cannot make me immortal? Tell me you know what immortality, Vidyamoksha said: Well spoken! You were dear to me; those words have made you dearer: Come, sit down. I will explain; meditate on what I say. | Bhedaibaranaya Book IV |
| | 3. | Shvetaketu said: My revered teacher cannot have known that, had he known it he would have told me. Therefore, Lord! Teach it. UddSlika said: I will teach it, my son! | Chhandoga Book VI |
| sage, lords, sages, nara, jayalil, lord, vaidyam, uddalka, wajstrawas, obey, whose, hirayana, blessed, show, devote, preached, riddle, told, siva, obey, shokuma, obay, self, reformed, godly, among, understanding, words, speaking, hirayana, hearer, scholars, migrant, asked, say, preached, what, tell, proclaims, shawsh, wondered, king, obey | Topic-3 | 1. From devotion, man gets faith; without devotion, he has none. Have devotion. I would have devotion, Lord! said Narada. | Atarreya Book VII |
| | 2. | Nothing, Lord! said Svetaketu. UddSlika said: My son! This great banyan tree has opening up from seed so small that you cannot see it. | Chhandoga Book VI |
| | 3. | Though a rich king, you have learnt the Vedas and the Upanishads; where will you go, when you leave this world? Janaka said: Lord! I do not know where I shall go. | Bhedaibaranaya Book VI |
| self, self, existent, oneself, desires, eternal, beings, desire, self, will, desire, devotion, worship, self, depending, soul, worshipper, gods, godly, worship, worshipping, self, existing, spirit, god, worshipping, whoever, self, inner, devotion, devotion, spirit, spiritual, however, oneself, existing, immortal, desires, own, self, creator, loving, whatever, rabb, belongs, individual, godliness, basking, spiritual, wisdom, divine, mindless, whose, arrogant, soul | Topic-4 | 1. Gods adore that Self; thereby they go where they will; satisfy every desire. Who discovers and knows the Self, goes where he will; satisfies every desire. | Chhandoga Book VIII |
| | 2. | He is imperishable among things that perish. Life of all, He, though one, satisfies every massive desire. He that dare discover Him within, knows peace; what other dare know peace? | Katha Book II |
| | 3. | He who desires one thing after another, brooding over them, is born where his desires can be satisfied; but the Self attained, one desire satisfied, all are satisfied | Mundaka Book III |
| immortality, death, immortality, life, deathless, dead, mortality, life, dying, immortality, eternal, mortal, alive, soul, incarnation, lives, soul, living, units, heaven, existence, heaven, existing, being, funeral, paradise, live, lived, sorrowless, spirit, heavens, spirit, sacred, unchanging, misery, killing, spiritual, die, heavenly, killed, but, spirit, sacrificed, sorrow, perpetual, birth, dead, born, sacrificer, grief | Topic-5 | 1. The ignorant man runs after pleasure, sinks into the entanglements of death; but the wise man, seeking the unity, does not run among things that die. | Bhedaibaranaya Book VII |
| | 2. | When all desires of the heart are gone, mortal becomes immortal, man becomes Spirit, even in this life. | Katha Book II |
| | 3. | The living man who finds Spirit, finds Truth. But if he fail, he sinks among fowler shapes. The man who has not found Spirit, in every creature, clings; neither to this nor that, attains immortal life. | Kena Section 2 |
| eternal, everything, being, immortality, immortal, every, everybody, earthly, all, containing, whatever, forever, existing, whoever, everyone, self, existent, immortal, nothing, completely, omnipotent, himself, whoever, omnipresent, spirit, celestial, self, existence, heavenborn, but, spirit, soul, earth, worldly, spirit, anything, heavenly, perpetual, nobody, each, whatever, self, being, wholly, truth, unifying, truth, eternal | Topic-6 | 1. Is he the only of all beings; all beings the honor of Self. The bright eternal Self that lives in a man, is one and the same; that is immortality, that is Spirit, that is all. | Bhedaibaranaya Book V |
| | 2. | The wise know Him, the all pervading, all illuminating, all knowing, the One, upholder of all, and say that He rises as the sun that He may warm everything, go into everything, insatiable power. | Prasha Question 2 |
| | 3. | Truth is the honor of all beings; all beings the honor of truth. The bright eternal Self that is truth, the bright eternal Self that lives as the truth in man, are one and the same; that is immortality, that is Spirit, that is all. | Bhedaibaranaya Book VII |
| meditation, meditating, meditates, spiritual, spirit, meditated, meditate, meditations, spirit, worship, worshipping, worshipping, worshipping, worshipping, worshipping, mindless, worships, soul, mind, contemplation, mind, devotion, devotion, eternal, immortality, sacred, desire, mental, adoration, desire, divine, transcending, yoga, transcends, devotions, ritual, transcends, immortal, chakra, mind, material, ritual, cults, self, existent, heavenly, godliness, venerable, heaven, imagination, awakened, enlightened | Topic-7 | 1. Who worships name as Spirit, moves within the limits of what is named, as it may please him, provided he worships it as nothing but Spirit. | Chhandoga Book VII |
| | 2. | Bhusha meditation and found that mind is Spirit. From mind all things are born, by mind they live, towards mind they move, into mind they return. | Taittireeya Book III |
| | 3. | A bow down to Spirit as the sole object of desire, the god of all desires; worship Spirit as the master of all, become the master of all, WorShip as the destroyer, your enemies whether public or in your own house shall be destroyed. | Bhedaibaranaya Book VIII |
| self, oneself, self, existent, self, will, himself, self, dependent, self, creator, self, existent, self, born, depending, self, interest, owns, himself, all, selves, self, created, yourself, self, controlled, own, solitude, soul, self, control, loneliness, yourselves, eternal, alone, independence, solitary, lonely, individual, impersonal, master, beings, personality, who, know, wisdom, images, listen, voice, words, tongue, silent, thoughts, omniscient, inspiration, ages, speaks, emotion, imagination, tastes | Topic-8 | 1. The thinking Self is the soul of the living Self, but within it lies its complement and completion, the knowing Self. The knowing Self grows up side by side with the thinking Self. | Taittireeya Book III |
| | 2. | I put Self instead of I, I say, the Self is below, above, in front, to the right, to the left. The Self is everything. The personal Self is the impersonal Self | Chhandoga Book VII |
| | 3. | My self! Who knows the impersonal Self, wherein the personal self, the living fires, senses, elements live, he knows all; lives in all. | Prasha Question 5 |
| senses, mindless, minds, mind, breath, breath, breathless, breath, silence, breath, spirit, hearing, sense, ear, smelling, breath, heal, ears, song, being, spirit, smell, speech, hear, hearer, smell, spoken, soul, sensuality, eternal, intellect, heard, who knows, wisdom, images, listen, voice, words, tongue, silent, thoughts, omniscient, inspiration, ages, speaks, emotion, imagination, tastes | Topic-9 | 1. He is the immov Self of all. Fire, His head; sun and moon, His eyes; the four quarters, His cars; revelation, His voice; wind, His breath; world, His heart, His feet. | Mundaka Book II |
| | 2. | In Spirit, he attains heaven, conquers his mind; becomes master of speech, sight, hearing, knowledge. All these said about that they hold the balance. | Taittireeya Book I |
| | 3. | The Sage said: The powers are: air, fire, water, earth, speech, mind, light, hearing. All these said about that they hold the balance. | Prasha Question 2 |
| dreamless, asleep, sleep, wakes, sleeping, dreaming, being, sleep, dreams, wakefulness, woke, himself, awake, dream, immortal, but spirit, immortality, sleep, dead, mindless, self, existent, spirit, somewhere, unifying, existence, things, other, creatures, alive, waking, condition, darkness, heavenborn, heaven, dead, deadless, world, earthly, self, life, fearless, soul, oneself, mortal | Topic-10 | 1. Who is awake, who creates lovely dreams, when man is fast in sleep? That Person through whom all things live, beyond whom none can go; pure, powerful, immortal Spirit. | Katha Book II |
| | 2. | A wise man sees in Self, those that are alive, those that are dead, and gets what this world cannot give. An ignorant man treads on the ground, but do not know the gold that lies underneath; we pass into the Self during sleep, but do not know Him. | Chhandoga Book VIII |
| | 3. | The Self is the Adorable, who moves in dreams. He is the unaltered, immortal Spirit. | Chhandoga Book VIII |

**Fig 13.** Topics of the Ten Principal Upanishads and some of their relevant documents (Model: USE-HDBSCAN-UMAP).
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