Dynamics of Character Embeddings in Indian Mythology: A Physics-Informed Neural Networks Approach

Apurba Paul
Computer Science & Engineering
Institute of Engineering and Management, Saltlake, Kolkata
Kolkata, West Bengal, India
apurba.saitech2021@gmail.com

Anish Goswami
Computer Science & Engineering
Institute of Engineering and Management, Saltlake, Kolkata
Kolkata, West Bengal, India
anishgoswamiofficial@gmail.com

Sainik Kumar Mahata
Computer Science & Engineering
Institute of Engineering and Management, Saltlake, Kolkata
Kolkata, West Bengal, India
sainik.mahata@gmail.com

Dipankar Das
Computer Science & Engineering
Jadavpur University, Kolkata
Kolkata, West Bengal, India
dipankar.dipnil2005@gmail.com

Abstract

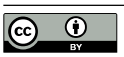
Transformer-based language models like BERT have transformed NLP through their deep contextualized embeddings. However, the layer-wise evolution of these embeddings remains underexplored, especially in narrative rich domains like Indian mythology, where prominent personalities or characters undergo semantic progression over time. In this paper, we present a continuous-time framework to model the dynamics of character embeddings from the Indian epic *Mahabharata*. We treat BERT's embedding transitions as trajectories in a latent dynamical system governed by ordinary differential equations, and propose a Physics-Informed Neural Network (PINN) that incorporates narrative metadata to regularize this evolution. Experiments on six major characters, each playing a pivotal role in the narrative, reveal that contextual embeddings evolve smoothly and predictably across layers. Our PINN model aligns closely with true embeddings while maintaining interpretability through constraints like smoothness, norm conservation, and narrative consistency. This framework bridges neural model interpretability with cultural narrative analysis, opening new directions for temporally-aware NLP and domain-specific embedding modeling.

CCS Concepts

• **Computing methodologies** → **Neural networks**; **Natural language processing**; • **Information systems** → *Document representation.*

Keywords

BERT embeddings, Physics-Informed Neural Networks, Mahabharata, semantic dynamics, narrative modeling



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1 Introduction

Transformer-based language models like BERT [3] have revolutionized NLP by producing rich contextual embeddings through multi-layer self-attention. While prior work in *BERTology* [19] has analyzed layer-wise behavior, the dynamics of embedding transitions across layers remain largely opaque especially in narrative domains where meaning evolves with story progression.

Although BERT already computes layerwise transitions via self-attention, these transitions are discrete and opaque. Our goal is not to re-implement BERT, but to approximate its hidden-state evolution with a continuous-time surrogate model. This enables us to study embedding dynamics as smooth trajectories, quantify their stability, and explicitly integrate narrative metadata, analyses that are not possible with raw BERT activations.

Narrative texts such as epics portray characters whose semantic representations shift over time, reflecting changes in relationships, roles, or morality. These evolving semantics are often encoded in the layer-wise transitions of transformer models, yet most analyses treat them as discrete steps. We argue for a continuous-time view of embedding evolution that better captures both model-internal transitions and narrative-driven semantic drift.

In this paper, we model character embeddings in the *Mahabharata*[1], a foundational Indian epic rich with temporally grounded character arcs. We propose a differential framework where embedding dynamics are governed by latent ordinary differential equations, learned via a Physics-Informed Neural Network (PINN). By integrating narrative metadata (e.g., parva, chapter, sentence_number), our model enforces smoothness, consistency, and semantic stability across layers.

[1] https://www.wisdomlib.org/hinduism/book/the-mahabharata-mohan