

# Visualizing High-dimensional Ball-Embeddings while Keeping Topological Relations<sup>\*</sup>

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**Abstract.** Region-based embeddings have been proven to be useful in knowledge graph reasoning. Existing visualization tool cannot preserve topological relations among high dimensional regions. We present a tool for visualizing high-dimensional balls that keeps topological relations after their dimensions are reduced to 2-dimensions. The first version of this tool provides four functions as follows: (1) Simple diagrammatic reasoning for syllogism; (2) diagrammatic reasoning with back-ground knowledge; (3) visualizing the construction process of ball-embeddings; (4) providing a web-service to impose a taxonomy structure onto its vector embeddings with zero-energy loss. A demonstration video of this tool is available at . . . .

**Keywords:** Diagrammatic reasoning · ball embeddings · visualization.

## 1 Introduction

Bing able to learn from data, and robust to noisy inputs, Deep-Learning has been successful in a variety of AI tasks that have frustrated classic symbolic approaches for decades, such as object classification, machine translation, voice recognition, question-answering [?]. However, Deep-Learning Systems lack of explainability, can be fooled [?, ?, ?], and normally need much more learning data than human does [?]. This introduces potential dangers into safety critical applications, such as autonomous driving. Introducing innate structures into Deep-Learning system has been advocated, and listed as one of the AI research topics in the Townhall meeting at AAAI-19, so that Deep-Learning research shall solve logical reasoning tasks (System 2 of mind) [?, ?]. As logical reasoning, such as Syllogism, is better represented by inclusion relations among regions, instead of translation among vectors [?, ?], recent researches have been attempting to promote vectors into regions to improve performances of logical query, triple classification, link prediction of Knowledge Graph [?, ?, ?, ?, ?].

The popular tool t-NSE [?] for visualizing vector embeddings cannot be directly applied for visualizing ball embeddings, for the dimensional reduction

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process of t-NSE does not guarantee the topological relations among balls. In this paper, we demonstrate an open source system that is able to visualize ball embeddings while keeping their topological relations. The main contributions of this system are as follows: (1) it has an vivid interactive user interface that can be used for diagrammatic reasoning among taxonomy; (2) it provides an effective and friendly approach for debugging the geometric construction process of ball embeddings; (3) it provides a batch service that accepts a large scale input for construct ball embeddings.

## 2 The Architecture

In order to provide useful visual feedback for the construction process of the ball embeddings the user needs to provide a history of the construction of their ball embeddings. In order to make the system more accessible and allow for quick demonstrations purposes we allow the user to alternatively provide a set of words along with their taxonomy. Using the approach of [ ] we then compute a set of high quality word embedding along with their construction history.

To make the system accessible from almost any modern device we chose to expose the user interface through a website. The user request is accepted by a flask web-server and placed in compute queue to allow for concurrent access and real-time feedback for the user even if the server is busy.

Finally given the ball embedding history we determine for every step if any two N-balls intersect, contain each other or are separate. This allows us to create a visual feedback reminiscent of a debugger of the N-balls construction along with a input taxonomy as a tree. Not only can the user see when his approach violates the taxonomy but also how and with which participant.

## 3 Services

### 3.1 Simple Diagrammatic Reasoning

#### Case 1

- user inputs: Socrates is human, human is animal
- user query: what is the relation between Socrates and animal
- system draw: (1) Socrates ball inside human ball, (2) human ball inside animal ball;
- system merges (1) and (2) [the human balls in (1) and (2) may have difference sizes]
- system conclude: Socrates is animal.

#### Case 2

- user input: Soccer is not human, human is mortal
- user query: what is the relation between Soccer and mortal

- system draw: (1) Soccer ball outside human ball, (2) human ball inside mortal ball;
- system merges (1) and (2)
- system randomly generates Soccer balls, and keep those balls outside human ball
- system conclude: undecided.

### 3.2 Diagrammatic Reasoning with Background Knowledge

- user input: Soccer is not human, human is animal
- user query: what is the relation between Soccer and animal
- system replaces ‘Soccer is not human’ with ‘Soccer is entity’, system adds ‘animal is entity’ by searching background knowledge

```
>>> from nltk.corpus import wordnet as wn
>>> soccer = wn.synsets('soccer')
>>> soccer
[Synset('soccer.n.01')]
>>> soccer = wn.synsets('soccer')[0]
>>> soccer
Synset('soccer.n.01')
>>> human=wn.synsets('human')[0]
>>> human
Synset('homo.n.02')
>>> soccer.lowest_common_hypernyms(human)
[Synset('entity.n.01')]
>> % check 'animal' and 'entity'
>> ..
```

- system draw: (1) Soccer ball outside animal ball, (2) human ball inside animal ball; (3) they are inside entity ball
- system merges (1), (2), and (3)
- system conclude: Soccer is not animal.

### 3.3 Visual Debugging

- user input: a tree structure, vector embeddings of tree nodes
- System will demonstrate the geometric construction process of ball embeddings in an interactive manner. That is, user clicks a button, System performs one geometric transformation and update the interface

### 3.4 Batch Service

- user provide her/his name and contact email.
- user input: a tree structure, vector embeddings of tree nodes
- System will construct ball embeddings at backend, and send the user the link fo the final ball embeddings

## 4 Conclusion and Outlooks

link to the video