Visualizing Ball-Embeddings of Taxonomy Structure *

First Author[1], Second Author[1], Third Author[1], Forth Author[1], and Fifth Author[1,2]

[1] University of Bonn, Germany
[2] {}@uni-bonn.de
[3] Fraunhofer IAIS, Germany

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

1 Introduction

Taxonomy, as a classification of concepts, exists in almost every disciplinary, such as file systems in computer science, classification of viruses, plants, and animals, government organization of a country. Though a powerful tool for learning from data, Deep Learning limits itself in representing everything as vectors, and can only approximate symbolic representation and reasoning. Taxonomy structure can be embedded by promoting vectorial embeddings learned from Deep Learning into balls in higher-dimensional space, such that (1) each vector embedding is well preserved by the central point of a ball; (2) symbolic tree structures are precisely encoded by inclusion relations among balls. Significant results are obtained in experiments on unifying word-embeddings with hypernym trees and on unifying entity-embeddings learned from knowledge-graphs and tree structures. Being able to precisely imposing external symbolic structures onto Deep Learning systems not only paves the way towards resolving the antagonism between connectionism and symbolicism in the literature, but also has tremendous value in real applications. For example, being able to impose traffic rules onto autonomous driving cars would ultimately solve the safety issue.

Ball embeddings are rigorously constructed by a sequence of geometric transformations under the condition that the loss function of the embedding must be zero, which is a condition that is not required and has not been targeted by Deep Learning approaches. This also raises the visualization problem of ball embeddings. The popular tool t-NSE for visualizing vector embeddings cannot be directly applied for visualizing ball embeddings, for the dimensional reduction 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

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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

Flask with task queue

draw a picture

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) Socarates 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