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Article / Book Information

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Title(English)	
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種別(和文)	論文要旨
Type(English)	Summary

(博士課程)  
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# 論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	情報工学 知能情報	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(工学)
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## 要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

This study explores the potential of the semantic specialization of word embeddings, leveraging lexical resources to enhance the representation of lexical semantics.

It assesses the feasibility of enhancing the performance in recognizing semantic relations between words and identifying the contextually appropriate word senses in a sentence by specializing word embedding---derived from large-scale textual data using deep learning methods---to the structural property of the semantic relations that are stored in lexical resources like WordNet.

Specifically, we propose two conceptually coherent methods. The first method incorporates the characteristics of the hierarchical structure inherent in the concept hierarchy of word meanings, such as transitivity and antisymmetry, into static word embeddings. Subsequently, the second method integrates the characteristics of the semantic network structures, such as semantic relatedness and unrelatedness arising due to the connections between words and word senses, into contextualized word embeddings. We empirically evaluate the effectiveness of the specialized embeddings by applying them to the hypernymy detection task and Word Sense Disambiguation task.

In the first method, we focus on the hypernymy detection between words through the adaptation to the concept hierarchy. This approach transforms static word embeddings into M-ary N-digit hierarchical code representations. Here, hypernyms and hyponyms share the first n digits. This enables the inference of hyponymy relations, aligning with the transitivity and antisymmetry inherent in the hierarchical structure of concept hierarchies. The primary challenge of the proposed method lies in optimizing the function that transforms embeddings into discrete hierarchical codes. This optimization uses gradient descents and hypernym-hyponym word pairs, extracted from the lexical resource, as supervision signals. To address this challenge, we introduce two concepts: the continuous relaxation of code representations and the metric that quantifies the degree of inclusion between code representations as continuous values. Additionally, we incorporate the auxiliary task, which involves reconstructing the input word embeddings from the code representations. We also use random sampling of non-hypernymy but semantically similar word pairs as negative examples. We then applied the degree of inclusion relation among transformed hierarchical codes to resolve the hypernymy detection task suites. As a result, we confirmed that the proposed method outperformed previous methods in the hypernymy classification task. Error analysis indicated that the hierarchical codes effectively capture concept abstractness through the non-zero digit length. However, they occasionally conflate meronymy (whole-part) relations with hyponymy relations, both possessing hierarchical structures. We also examined the characteristics of the hierarchical code assignments to words. We revealed a weak agreement with the structural properties of WordNet's concept hierarchy, such as semantic similarity between words. A key limitation of the first method is its inability to address the context-dependent meanings of polysemous words, stemming from its reliance on static word embeddings. Moreover, it does not leverage knowledge of semantic relations that do not form concept hierarchies, predominant in adjectives and adverbs.

Conversely, in the second method, we focus on the Word Sense Disambiguation through the adaptation to the semantic networks. This approach transforms the embeddings of the word senses and target words in contexts derived from the contextualized embeddings. This ensures that the similarities between target words and word senses---as well as among word senses themselves---represent their semantic relatedness, like adjacency and neighborhood, within the semantic network. To address the challenges associated with training transformation functions for selecting the semantically closest senses of target words in context, we employ joint optimization of two objectives: the Attract-Repel objective for sense pairs and the self-training objective for target words and word senses. Additionally, we introduce constraints to the transformation functions to limit deviations from the similarities observed in pre-specialized embeddings. We employ specialized

embeddings to disambiguate word senses by choosing the nearest neighboring senses to the target words. Consequently, we confirmed that the proposed method outperformed previous methods in the knowledge-based Word Sense Disambiguation task. We analyzed the similarity characteristics of specialized embeddings and revealed that aligning with the relatedness within the semantic network effectively brings semantically related senses and words closer and sends different senses of the same word or unrelated senses farther away. Furthermore, we observed that the similarities among related, different, and unrelated senses are in sync with the WSD task performance.

Two predominant methodologies represent word meanings: one is word embedding, grounded in statistical methods, and the other is lexical resources, rooted in human knowledge. This research unveils that specializing pre-trained embeddings to the hierarchical and network structures of word meanings in lexical resources contributes to improving the performance in the lexical semantics tasks, such as hypernymy detection and Word Sense Disambiguation. These findings offer insights into semantic specialization of word embeddings and highlight the potential of integrating deep learning-based embeddings with lexical knowledge to achieve better semantic understanding.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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