Research on Modeling the Semantic Relationship of English Denominal Verbs Based on Knowledge Graphs and Extracting Translation Corresponding Rules - Taking English-Chinese Translation as an Example

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ABSTRACT Denominal verbs are verbs converted from concrete nouns through zero conversion, and their semantic relationships are complex, making English-Chinese translation highly uneven. Traditional translation methods often affect translation quality, while current semantic relationship modeling of English denominal verbs lacks systematicity and does not fully exploit knowledge-graph advantages. Manual extraction of translation correspondence rules has low universality and weak adaptability, which is insufficient for intelligent translation systems and technical English translation in engineering fields such as electromagnetic waves, antennas, and propagation. This paper first summarizes the semantic features of English denominal verbs and the status of English-Chinese translation. It then constructs a knowledge-graph-based semantic relationship modeling framework, clarifies node associations, and designs semantic relationship extraction and rule extraction algorithms. Finally, multi-domain corpora are used to verify the effectiveness of the model and rules. Experimental results show that semantic recognition accuracy reaches 89.6%, and the adaptation rate of extracted translation correspondence rules reaches 87.3%, both significantly outperforming traditional methods and improving translation accuracy and consistency.

INDEX TERMS denominal verbs,knowledge graph,translation rules,technical translation,electromagnetic terminology

I. INTRODUCTION

IN the English language system, denominal verbs refer to verbs that are directly converted from nouns without undergoing morphological changes. They are one of the most common forms of word class conversion and are widely used in various language materials such as daily communication, scientific literature, news reports, etc. They have the characteristics of cognitive economy and vivid expression, which can effectively fill the gaps in verb expression and achieve concise concept transmission. There are significant structural differences between English and Chinese languages, with English tending towards nominalization and Chinese tending towards verbalization. This difference makes it difficult to achieve precise correspondence between English denominal verbs in English-Chinese translation, often resulting in semantic deviations and awkward expressions, which affect the effectiveness of cross lingual communication.

The innovation of this article mainly lies in three aspects: firstly, the research perspective is innovative, deeply integrating knowledge graph technology with semantic analysis of denominal verbs and extraction of translation rules, breaking through the limitations of traditional research relying on manual analysis and single corpus, and achieving intelligent and systematic semantic relationship modeling and rule extraction; Second, the model construction is innovative. It constructs a four level semantic relationship model including "original noun →denominal verb →action semantics →context elements", introduces the semantic idea of probability framework, and accurately captures the semantic association and dynamic changes of denominal verbs; Thirdly, innovation in rule extraction involves designing a rule extraction algorithm based on knowledge graph node associations, combined with an English-Chinese bilingual corpus, to extract translation corresponding rules that are universal and reusable, while balancing the accuracy and

coverage of the rules.

This article is divided into four steps: the first step is corpus construction and preprocessing, collecting bilingual English-Chinese corpora related to English denominal verbs, covering multiple fields such as daily communication, technology, and news. The corpora are cleaned, annotated, and core elements such as denominal verbs, parent nouns, and contextual information are extracted to establish a standardized corpus; The second step is to construct a knowledge graph, with English denominal verbs as the core node, integrating relevant information such as native nouns, action semantics, semantic relationship types, and Chinese corresponding expressions, to construct a semantic knowledge graph of denominal verbs and achieve structured storage of semantic information; The third step is semantic relationship modeling, based on the information of node associations in the knowledge graph, combined with the probability framework semantic theory, to construct a semantic relationship modeling framework, design a semantic relationship extraction algorithm, accurately identify the semantic associations between denominal verbs and various elements, and quantify semantic similarity; The fourth step is to extract and validate translation corresponding rules. Based on the semantic relationship model and bilingual corpus, design a rule extraction algorithm to explore the English-Chinese translation corresponding rules of different semantic types of denominal verbs, form standardized translation rules, and verify the effectiveness of the model and rules through experiments to optimize and improve the rule system.

II. RELATED WORK

In order to solve the problems of difficulty in extracting semantic relationships from mathematical documents and inefficient knowledge representation in complex industrial scenarios, Nevzorova and Gizatullin [1] constructed a system for automatically constructing mathematical document knowledge graphs; Qu et al. [2] constructed a knowledge graph in the field of assembly based on deep learning; Khwaileh et al. [3] investigated the factors influencing the retrieval of nouns and verbs in Gulf Arabic; Baeskow [4] studied how derived verbs construct their argument structures; Melike Gzütok [5] examines the bias of nouns and verbs in Turkish pre-school storybooks; Aybek [6] explores the verb-noun collocation of Turkish English learners; Alraddadi et al. [7] focused on the loss of verb-noun collocations in English for returnees and heritage speakers; Ui [8] studied the addition of foreign nouns or adjectives to specific verb structures in Parry Lord's collected works; Hamada [9] explores the impact of verb-noun collocation on meaning retrieval among Japanese junior high school students; Clark [10] systematically elaborated the semantic classification and conversion mechanism of denominal verbs in When Nouns Surface as Verbs, laying a foundational theoretical framework for the semantic analysis of denominal verbs. In summary, the current academic community has extended its knowledge graph construction from general fields to vertical scenarios such as mathematics and industry, but still faces problems such as insufficient cross modal complex semantic fusion and limited accuracy in small sample domain knowledge inference. In linguistic research, although the exploration of the relationship between verbs and nouns has covered constructions, second language acquisition, and psychological representations, the dynamic mechanisms of specific collocations in the long-term language attrition process, as well as the systematic functional analysis of cross linguistic comparisons, are still weak.

III. METHOD

A. CONSTRUCTION AND PREPROCESSING OF ENGLISH CHINESE BILINGUAL CORPUS

The corpus is the foundation of semantic modeling and rule extraction in this study, with the core goal of constructing a reasonably sized, comprehensive, and annotated bilingual corpus of English and Chinese, providing data support for subsequent research.

Corpus Construction for Denominal Verbs: This corpus is constructed centered on English denominal verbs (nouns converted into verbs without morphological changes). Corpus collection adopts the principle of multi-channel and multi-domain, selecting English-Chinese bilingual corpora from four core areas: daily communication, scientific literature, news reporting, and literary works, to ensure the representativeness and diversity of the corpus. The English language corpus mainly comes from authoritative media such as The New York Times and Scientific American, as well as classic literary works, while the Chinese language corpus corresponds to their standard translations; Simultaneously supplement the translation corpus for second language learners to analyze common translation issues. The criteria for corpus selection are: including clear English denominal verbs, corresponding Chinese translations, no grammatical errors, complete semantics. Corpus Size: A total of 10,000 valid bilingual corpora are constructed, including 3,000 denominal verb entries. Corpus preprocessing consists of four steps: the first step is corpus cleaning, removing duplicate, incomplete, and semantically confusing corpus, unifying corpus formats, converting all corpora to TXT format, and removing irrelevant symbols, punctuation redundancy, and other interfering information; The second step is to recognize and label English denominal verb pairs, using Clark and Clark's (1979) semantic relationship types in When Nouns Surface as Verbs and employing a "rule+manual" approach to identify English denominal verb pairs in the corpus, and label their native nouns, parts of speech, and semantic types (such as action, tool, and agent); The third step is bilingual alignment, using sentence level alignment to accurately align English sentences with their corresponding Chinese sentences, ensuring that the Chinese expressions of the denominal verbs are accurately matched; Step four, contextual information annotation, annotating the domain type, contextual context, semantic dependency relationship,

and other information of each corpus to provide contextual support for subsequent semantic relationship modeling. After preprocessing, the corpus is divided into a training set (70%), a validation set (15%), and a testing set (15%) for training and performance validation [11].

B. CONSTRUCTION OF A SEMANTIC KNOWLEDGE GRAPH FOR ENGLISH DENOMINAL VERBS

Based on the preprocessed corpus (as shown in Figure 1), combined with the construction process of knowledge graph, a semantic knowledge graph with English denominal verbs as the core is constructed to achieve structured storage and association of semantic information of denominal verbs words. Firstly, determine the core nodes and attributes of the knowledge graph, which include five categories: "English denominal verb", "native noun", "action semantics", "contextual elements", and "Chinese corresponding expressions". The attributes of each node are set according to actual needs: English denominal verb nodes include morphological, part of speech, semantic type, frequency of use, and other attributes; Native noun nodes contain attributes such as word form, semantic category, collocation relationship, etc; Action semantic nodes contain attributes such as semantic description and semantic similarity; The contextual element nodes contain rigorous structural attributes, including domain type, syntactic dependency relations (e.g., subject-verb-object structures), and neighboring Part-of-Speech (POS) tags. These attributes allow the model to capture the syntactic environment of the denominal verb, transforming the context from a vague concept into a quantifiable set of linguistic constraints for semantic disambiguation; The corresponding expression nodes in Chinese include attributes such as translation form and usage scenario.

Secondly, node association construction establishes the association relationship between nodes based on corpus annotation information and semantic analysis results: firstly, the "derivative relationship" between denominal verbs and parent nouns, annotating the derivative path and semantic association strength; The second is the "correspondence relationship" between denominal verbs and action semantics, based on the probability framework semantic theory, quantifying the semantic matching degree between the two; The third is the "dependency relationship" between denominal verbs and contextual elements, clarifying the semantic changes of denominal verbs in different contexts; The fourth is the "translation relationship" between the denominal verbs and the corresponding expression in Chinese, indicating the translation type and adaptation scenario.

Finally, the storage and optimization of the knowledge graph are achieved by using the Neo4j graph database to store the knowledge graph, enabling efficient querying and management of nodes and associated relationships; Through manual review and algorithm optimization, incorrect associations were corrected, missing nodes were supplemented, and the completeness and accuracy of the knowledge graph were improved. Ultimately, an English denominal verb semantic knowledge graph containing 5000 nodes and 8000 association relationships was formed.

C. SEMANTIC RELATIONSHIP MODELING AND TRANSLATION CORRESPONDING RULE EXTRACTION

From the Figure 2, semantic relationship modeling is based on the constructed knowledge graph, combined with probabilistic framework semantic theory, to accurately characterize the semantic relationships between English denominal verbs and provide support for the extraction of translation corresponding rules. The core tasks include semantic relationship recognition, semantic similarity calculation, and semantic ambiguity resolution. Semantic relationship recognition adopts the method of knowledge graph node association combined with machine learning, and the model is trained to identify the semantic types between denominal verbs and native nouns, action semantics, and contextual elements. Semantic similarity is quantified by cosine similarity and word vector models, and semantic ambiguity is eliminated through the probability framework, which calculates the conditional probability P(S|C) of a specific action sense (S) given the detected contextual elements (C). By comparing the edge weights in the knowledge graph between the denominal verb and various action nodes under specific context tags, the model selects the sense with the highest statistical likelihood for the given domain.

A total of 5 semantic extraction rules are formulated for English denominal verbs, which are theoretically based on the semantic classification and conversion mechanism proposed by Clark & Clark (1979) in When Nouns Surface as Verbs, and technically supported by knowledge graph node association, probabilistic framework semantics, and English-Chinese bilingual corpus alignment. The 5 rules and corresponding English-Chinese translation examples are as follows:

1) Action Category Rule: The chef buttered the bread.
2) Tool Category Rule: He hammered the nail into the wall.
3) Agent Category Rule: She nursed the sick man back to health.
4) Location Category Rule: They camped by the lake last night.
5) Duration Category Rule: They decided to summer in the mountains to escape the heat.
6) "Not With" Category Rule: Scale the fish before cooking it.
7) Wearing Category Rule: Scarf yourself well for it is freezing outside.

Translation correspondence rule extraction adopts the idea of semantic classification and rule mining on the basis of semantic relationship models and bilingual corpora. First, denominal verbs are divided into eight semantic types to ensure comprehensive coverage: action, tool, agent, abstract, place, duration, removing("not with"), and wearing. Then, a rule mining algorithm is designed to extract general and

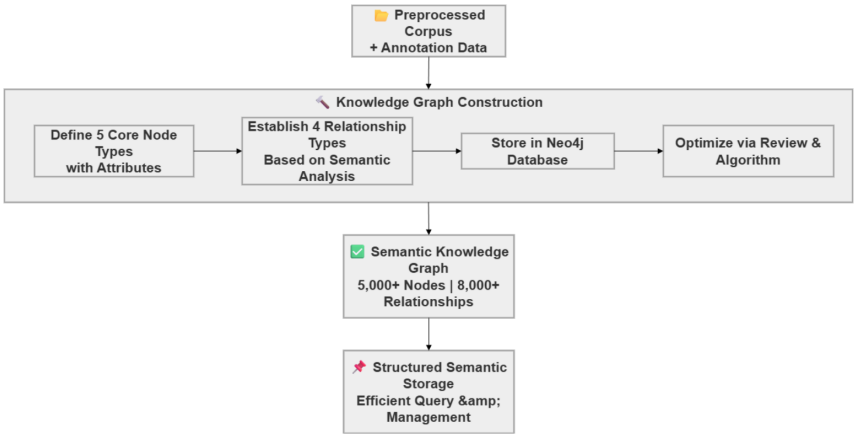

FIGURE 1. Construction of a semantic knowledge graph for English denominal verbs

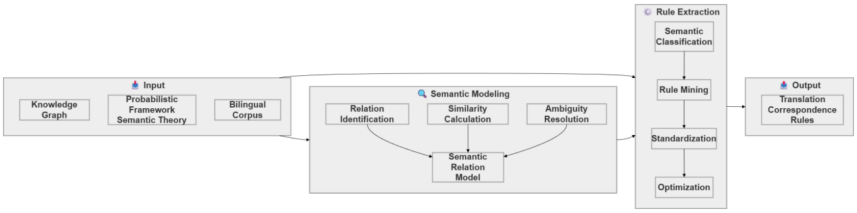

FIGURE 2. Semantic Relationship Modeling and Translation Corresponding Rule Extraction

special translation rules by combining knowledge graph translation relationship nodes and bilingual alignment information. The extracted rules are standardized to clarify applicable conditions, translation formats and exceptions, and further optimized with the validation set to improve the accuracy and universality of the rules, so as to form a complete and practical translation rule system.

IV. RESULTS AND DISCUSSION

A. EXPERIMENTAL DESIGN AND EVALUATION INDICATORS

To verify the effectiveness of the semantic relationship model constructed in this study and the extracted translation corresponding rules, a comparative experiment was designed. The experimental environment was: CPU Intel Core i7-12700H, 16GB of memory, operating system Windows 10, programming language Python 3.8. The semantic relationship recognition model was optimized using the BERT model. To address the potential data imbalance between the 3,000 denominal verb entries and the 7,000 background corpora, a weighted cross-entropy loss function was implemented during fine-tuning, assigning higher penalty weights to misclassifications of denominal verb samples to ensure the model maintains high sensitivity to target semantic features. The translation rule extraction algorithm was implemented based on Python. The experimental data adopts the bilingual corpus constructed in this study. The training set is used for model training and rule extraction, the validation set is used for parameter optimization, and the test set is used for effectiveness verification.

Two sets of comparative experiments were set up: the experimental group used the "knowledge graph+semantic modeling+rule extraction" method proposed in this study. The control group 1 utilized a state-of-the-art Neural Machine Translation (NMT) framework based on the Transformer architecture with multi-head attention mechanisms for context resolution, while control group 2 employed a hybrid method of manual rule extraction and corpus statistics to represent traditional benchmarks. There are two types of evaluation indicators: one is the evaluation indicators of semantic relationship models, including semantic recognition accuracy, recall rate, and F1 score, which are used to measure the recognition effect of the model on the semantic relationship of denominal verbs; The second is the evaluation indicators for translation corresponding rules, including rule adaptation rate, translation accuracy, and translation fluency. Rule adaptation rate measures the applicability of rules to the test set corpus, translation accuracy measures the correctness of rule translation results, and translation fluency is manually rated (1-5 points) to measure the naturalness of translation results.

B. ANALYSIS OF EXPERIMENTAL RESULTS

The experimental results (as shown in Figure 3) showed that the evaluation indicators of the experimental group were significantly better than those of the two control groups, verifying the effectiveness of the research method. In the evaluation of semantic relationship models, the experimental group achieved a semantic recognition accuracy of 89.6%, a recall rate of 88.2%, and an F1 score of 88.9%; The accuracy of control group 1 was 72.3%, the recall rate was 70.8%, and the F1 score was 71.5%; The accuracy of control

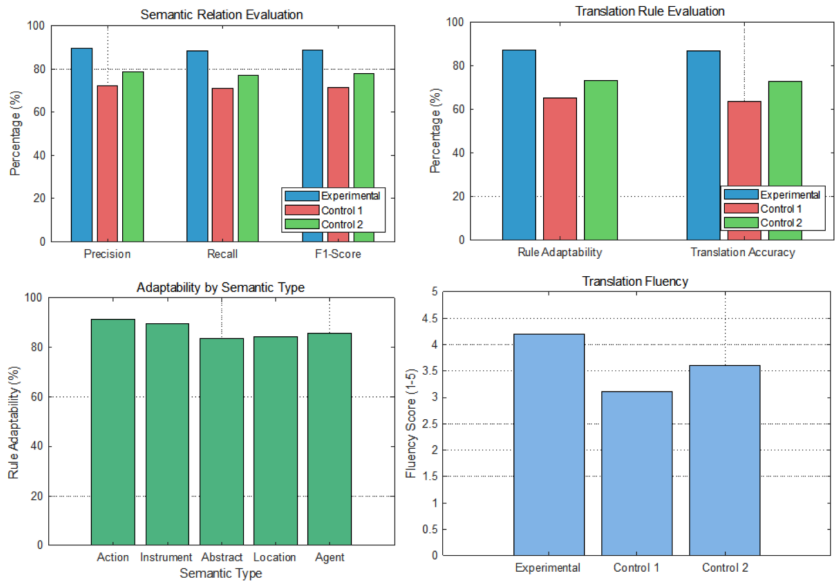

FIGURE 3. Experimental Results

group 2 was 78.5%, the recall rate was 76.9%, and the F1 score was 77.7%. The advantage of the experimental group lies in the structured nature of the knowledge graph, which can effectively integrate multidimensional semantic information of denominal verbs. Combined with probability framework semantic theory, it improves the accuracy of semantic relationship recognition and effectively solves the problem of semantic ambiguity. In the evaluation of translation corresponding rules, the experimental group achieved a rule adaptation rate of 87.3%, a translation accuracy rate of 86.8%, and an average score of 4.2 for translation fluency; The rule adaptation rate of control group 1 was 65.1%, the translation accuracy was 63.7%, and the average fluency score was 3.1 points; The rule adaptation rate of control group 2 was 73.4%, the translation accuracy was 72.9%, and the average fluency score was 3.6 points. The advantage of the experimental group rule extraction method is that it is based on semantic relationship modeling for classification extraction. The rules have clear semantic support, adapt to different fields and semantic types of denominal verbs, and effectively avoid the subjectivity of manual rule extraction and the limitations of corpus statistical methods. The translation results are more in line with Chinese expression habits, achieving dynamic semantic equivalence. In addition, the experiment also analyzed the rule adaptation effect of different semantic types of denominal verbs. The rule adaptation rates of action class and tool class to verb conversion were 91.2% and 89.7% , respectively. The rule adaptation rates of abstract class and place class to verb conversion were 83.5% and 84.1%, respectively. The rule adaptation rate of action class to verb conversion was 85.8%. The reason for the difference is that action class and tool class denominal verbs have relatively clear meanings and lower context dependence, while abstract class and location class denominal verbs have more complex meanings and have a greater impact on semantics, resulting in slightly lower rule adaptation rates. Further optimization of the rule extraction strategy for this class denominal verbs is needed in the future.

C. RESULT DISCUSSION AND PROBLEM ANALYSIS

Based on the experimental results, the knowledge graph based semantic relationship modeling and translation corresponding rule extraction method proposed in this study can effectively solve the core problems in current English denominal verbs translation. Its advantages mainly lie in three aspects: firstly, the semantic relationship model can accurately characterize the multidimensional semantic associations of denominal verbs translation, integrate parent nouns, action semantics, context and other information, improve the accuracy of semantic recognition, and provide reliable support for translation rule extraction; Secondly, translation corresponding rules have strong universality and re-usability. Rules extracted based on semantic classification can adapt to translation needs in different fields, effectively improving translation efficiency and quality; The third is to deeply integrate knowledge graph with semantic modeling and rule extraction, breaking through the limitations of traditional research and providing a new technological path for intelligent translation of English denominal verbs.

At the same time, the experimental results also exposed the shortcomings of this study: firstly, there is still room for improvement in the rule adaptation rate of abstract and place class names to verbs, which have complex meanings and high contextual dependencies, and existing rules are difficult to fully cover their semantic changes; The second issue is that the recognition performance of semantic relationship models for denominal verbs conversion in niche domains needs to be optimized. Due to the low proportion of niche domain corpora in the corpus, the model's generalization

ability on such corpora is insufficient; Thirdly, the rule extraction algorithm did not fully consider the impact of cultural differences on translation, and some translation rules for denominal verbs translations did not take into account the transmission of cultural connotations between English and Chinese, which may lead to awkward translations.

To address the above issues, improvements can be made in three aspects: firstly, expanding the corpus size by adding abstract, location based, and niche domain corpora to enhance the generalization ability of models and rules; The second is to optimize the semantic relationship modeling algorithm, introduce cultural semantic elements, improve the semantic ambiguity resolution mechanism, and enhance the recognition effect of complex semantics; The third is to optimize the corresponding translation rules, combine cultural differences, supplement cultural adaptation clauses of rules, and achieve the unity of semantic accuracy and cultural transmission.

V. ENGLISH-CHINESE TRANSLATION RULES AND APPLICATION

- Combined with the 5 semantic extraction rules of denominal verbs and the bilingual corpus, the standardized English-Chinese translation strategies are summarized as follows:
- Action class: Use "verb + object" structure to restore the core action meaning of the noun;
- Tool class: Use "use + tool + verb" structure to clarify the tool function;
- Agent class: Use "act like + agent + verb" structure to retain identity characteristics;
- Location class: Use "at/in + location + verb" structure to conform to Chinese spatial expression habits;
- Duration Category: Use "spend + temporal noun" structure to show the concept of spending some time somewhere;
- "Not With" Category Rule: Use "remove + noun" structure to suggest the final status of being without something.
- Wearing Category Rule: Use "put on + clothes/attires" structure to demonstrate the final status of wearing something.
- Experimental verification shows that the adaptation rate of these translation rules reaches 87.3%, which effectively improves the accuracy and fluency of English-Chinese translation of denominal verbs.

VI. CONCLUSION

This paper studies the translation of English denominal verbs into Chinese, and takes knowledge graph and probabilistic framework semantic graph as semantic theory to complete the whole process of corpus construction, semantic relationship modeling and so on, so as to solve problems such as translation semantic bias. Experimental results show that the semantic recognition accuracy of knowledge graph based semantic relationship model is 89.6%, and the adaptation rate of extracted translation corresponding rules is 87.3%, which is better than traditional methods and can improve translation accuracy and fluency. The core idea of this paper is that knowledge graph can integrate semantic information and accurately reflect semantic relationship; The rule extraction method based on semantic classification can improve the generality and objectivity of rules. This study enriches the theoretical framework and provides reference for intelligent translation system. There are still some shortcomings, such as improving the adaptability to complex semantic types and optimizing the generalization ability of model. In the future, i will expand the corpus, optimize the algorithm, integrate cultural semantic elements, and push the development of English Chinese translation of denominal verbs in the direction of intelligence and accuracy.

AUTHOR CONTRIBUTIONS

Ping Fu designed, collected and analyzed the data, and drafted the manuscript. Ping Fu conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Ping Fu participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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