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博士の専攻分野の名称	博士（工学）
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学位論文内容の要旨

Peer review stands as a cornerstone in validating academic work and ensuring the quality of published research. The process, while essential, can be time-consuming for both authors and reviewers. Therefore, the development of an accurate system for predicting peer review scores holds immense potential in streamlining the process, reducing the workload of reviewers, and providing constructive feedback to authors. This dissertation addresses the challenges associated with implementing deep learning methods for predicting peer review scores, particularly in scenarios where labeled data is limited. Deep learning has emerged as a promising method for developing peer-review scoring systems. However, the requirement for substantial training data poses a significant challenge. Publicly available datasets for peer review are often constrained in size, impeding the creation of robust models. This research aims to overcome these challenges by introducing innovative transductive learning approaches that capitalize on the inherent structure within unlabeled data or insights from related tasks, enhancing the performance of peer review prediction models. Traditional deep learning methodologies involve fine-tuning language models (LMs) tailored for specific tasks. In response to limited resources for fine-tuning LMs, this

dissertation explores transductive learning approaches. Transductive learning aims to boost model performance by leveraging the inherent structure within unlabeled data or insights from related tasks. This novel approach highlights the versatility and effectiveness of incorporating diverse types of information in machine learning methodologies. An additional challenge addressed in this research revolves around the limitations of pretrained models, particularly Transformer-based models. While proficient in managing relatively short sequences, these models encounter difficulties when processing longer sequences. This dissertation proposes four distinct approaches to enhance peer review score prediction.

The first two approaches center on semi-supervised learning methods, addressing both truncated and full documents. Semi-supervised learning is a potent technique that combines labeled and unlabeled data during training, leveraging the wealth of information present in unlabeled datasets to enhance the model's understanding and overall performance. In the context of peer review score prediction, these approaches specifically focus on utilizing ladder networks within the semi-supervised learning paradigm. Ladder networks, a type of deep denoising autoencoder, are characterized by the incorporation of skip connections and reconstruction targets at intermediate layers. This architecture is trained to minimize combined supervised and unsupervised cost functions concurrently, employing backpropagation. The study emphasizes the use of ladder networks, particularly the Γ-model, which streamlines the decoder by retaining only the top layer. This modification facilitates seamless integration into various networks without the need for a separate decoder. A notable aspect of this research lies in its fundamental contribution to the integration of transformer-based models into the realm of semi-supervised learning, specifically within the framework of ladder networks. This integration is designed to optimize the model's ability to capture complex patterns and relationships in both labeled and unlabeled data, thereby enhancing its predictive capabilities for peer review scores. The study's outcomes are anticipated to provide valuable insights into the correlation between the quantity of unlabeled data and the observed performance enhancement in both the semi-supervised baselines and the proposed models. By delving into the interplay between model architecture, training methodology, and the availability of unlabeled data, this research aims to contribute valuable knowledge that can inform the development of more robust and effective semi-supervised learning approaches for peer review score prediction.

The third approach introduces a tailored form of transfer learning designed specifically for truncated documents. Transfer learning is a powerful technique involving the training of a model on a source task and subsequently transferring the acquired knowledge to a target task. The overarching

goal of this research is to enhance the model's capacity to comprehend and predict peer review scores from academic texts. This is achieved by training the model on a task that incorporates a larger set of related data, followed by the transfer of the acquired knowledge to the specific task of predicting peer review scores. A distinctive method employed in this approach is intermediate-task transfer learning for predicting peer review scores. This involves the initial fine-tuning of a pretrained model on an intermediate task, followed by subsequent fine-tuning on the target task. In this study, the intermediate task selected is the prediction of review-aspect sentiment. The choice of sentiment prediction as the intermediate task is grounded in the observation that the sentiment expressed in a review often correlates with the score attributed to the review. Additionally, the dissertation introduces a technique to extract aspect sentiments from a detailed review aspect annotation within the peer-review dataset. The experimental outcomes of this approach demonstrate the effectiveness of each intermediate task, showcasing notable performance improvements across all aspects of review score prediction. By strategically leveraging transfer learning with an intermediate task that captures sentiment nuances, the research contributes to refining the model's understanding of the intricate relationships within academic texts, ultimately leading to enhanced accuracy in predicting peer review scores.

The fourth approach delves into the realm of transfer learning specifically tailored for full documents, recognizing the distinctive characteristics and challenges posed by longer academic papers. The utilization of transfer learning for full documents seeks to address the limitations of pretrained models when confronted with extended sequences, ultimately facilitating a more comprehensive analysis and understanding of the content. The methodological approach involves segmenting the document into individual sentences and deriving a representation for each sentence from the pretrained LM. These sentence representations are then concatenated into a sequential format, serving as input for both intermediate-task training and subsequent fine-tuning on the target tasks. This process is designed to leverage the pretrained model's understanding of linguistic structures and contextual nuances, with a specific focus on the challenges presented by lengthier academic documents. The experimental findings from this approach yield crucial insights, underscoring the importance of models capable of effectively processing longer sequences. The results suggest that such models exhibit superior performance, providing a valuable contribution to the broader field of transfer learning for document analysis. By strategically adapting transfer learning techniques to accommodate the intricacies of full documents, this approach aims to enhance the model's ability to capture and comprehend the nuanced information embedded within extensive

academic papers, thereby contributing to more accurate and comprehensive peer review score predictions.

In conclusion, this dissertation makes significant contributions to the field of peer review prediction through the introduction of innovative transductive learning approaches and the strategic utilization of semi-supervised and transfer learning techniques. These proposed methods are specifically designed to tackle challenges arising from limited labeled data and the inherent limitations of pretrained language models in the context of peer review scoring. By integrating transductive learning, the research seeks to capitalize on the inherent structure within unlabeled data and insights from related tasks, enhancing the overall performance of peer review prediction models. The incorporation of semi-supervised learning techniques aims to optimize model performance by leveraging the combined information from labeled and unlabeled data. Furthermore, the adaptation of transfer learning, designed full documents, addresses the need for more robust models capable of handling long document lengths. The intermediate-task transfer learning adds an additional layer of sophistication by strategically fine-tuning the model on tasks related to sentiment prediction, thereby improving its understanding of the nuanced relationships within academic texts. The anticipated outcomes of this research extend beyond methodological advancements. The developed approaches are expected to significantly enhance the accuracy and efficiency of peer review scoring systems. This, in turn, stands to benefit authors and reviewers by streamlining the review process and providing more insightful feedback. Ultimately, the academic community at large is poised to reap the rewards of improved peer review prediction models, fostering a more efficient and constructive environment for scholarly discourse and advancement.

論文審査結果の要旨

令和 6 年 1 月 29 日 16:30 より, 論文題目 : Transductive Learning for Peer Review Score Prediction に関する学位論文審査，続く 17:30 より同論文に関する最終試験を実施した.

本研究は，英語を母国語としないアジア地域の大学生が執筆した論文を対象とし，「新規性」や「可読性」など，論文のクオリティに関する評価モデルを構築し，これを用い学生の採択に向けた論文推敲を支援するシステムを開発することを目的としている． 高精度な査読スコア予測を行うためには，少なくとも 2 つの問題に対処する必要がある．1 点目は，スコア判定に必要となるスコア付きの訓練データ数が少ないという問題である．2 点目は，投稿論文は約 8,000 単語以上からなるテキストであるため，入力が長系列であるという問題である．本研究は，1 点目の問題に対し，2 つの手法を提案している． 1 つは，大量のス

コアなしデータを利用することにより少量のスコアあり訓練データを効率よく学習する半教師付き学習の一つである Ladder Network と呼ばれる学習手法に事前学習モデルの一つである BERT を組み入れテキスト中の単語の意味を効率よく学習し半教師付き学習の精度を高めるという手法である．2 つ目の手法は，Intermediate-task training であり，事前学習と fine-tuning の間に補助的な学習モデルを取り入れることにより，スコア予測の精度向上を目指した手法である．各手法は，別紙 3 の論文 1, 及び 2 において公開されている．2 点目は，投稿論文は約 8,000 単語以上からなるテキストであるため，入力が長系列であるという問題である．本研究はこの問題に対し，SciBERT 埋め込み表現を SciBERT-SE, すなわち単語の埋め込み表現を文の埋め込み表現に変更し，さらにこの処理を intermediate task training の前処理として組み込むことにより, 512 単語から 512 文への埋め込みを可能とする手法を提案した．本手法は，別紙 3 の論文 3 において公開されている．

公聴会では，上記の内容に関する発表の後，審査委員から，1. ラベルなしデータ数が最大 1,000 しか実験を行っていないことに関する理由，2. ラベルなしデータをどのように補完(augmentation)しているのか，3. Data augmentation について，査読者はボーダーラインの論文，あるいは不採択の論文について詳細な査読結果を提示する．現在は査読結果を一律に扱っているようであるが，このことに関してどう考えるか，4. Ladder Network に基づく本モデルに関する処理の確認，5. なぜ Large Language Model(LLM)を利用しなかったのか、また利用の可能性，6. 実際に投稿論文をデータとして用いた場合，利用できるのかに関する質疑と議論があった．

続く最終審査では，LLM を本タスクに利用する場合の難しさに関する議論の他、博士論文について, 1. 各章の最終章を Conclusion から Summary に変更する, 2. 表裏空白のページが挿入されているため，確認する，3. 要旨が 1,500 未満であるため 1,500 になるよう加筆するなどの意見があった．投稿論文を入力とし各評価指標を予測するタスクにおいて少量の訓練データ数，及び入力の単語系列の制限という問題に対し提案した各手法において，全体精度は依然 8 割を下回っているものの，各手法には新規性が認められること，また定量的な実験を通して得られた結果のエラー解析を詳細に実施しまとめ，これらを 3 編の国際会議論文として公表していること，得られた手法をデモシステムとして公開していること，さらに Ladder Network に基づく手法では 2023 年度の言語処理学会年次大会において若手奨励賞を受賞していることなどから，本学の博士として相応しいと判断し，論文審査，及び最終審査委を合格とした．