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Thesis Outline

This thesis presents frameworks for a table-to-text generation with numerical reasoning. We elaborate tables from scientific papers with unknown schemas as data sources. Due to the difficulties of determining the semantics of a table with an unknown schema, there is a big challenge in understanding a table only on the basis of its functional areas: headers and cells. In this study, we address one part of table header semantic problems, metric-type identification, as our first subtask, which is important in supporting arithmetic operations over tables to obtain pre-executed arithmetic operation results as inferred facts. Then, we use both explicit and inferred facts derived from table contents to solve the second subtask, the table-to-text generation with numerical reasoning. The thesis consists of 6 chapters, and the summary of each chapter is described as follows.

Chapter 1 describes the general background and objective of the thesis. First, we describe the importance of data-to-text applications. The increasing demand for data-to-text applications has encouraged further studies on generating better output text. We then present the challenges of data-to-text generation tasks in generating more analytical text with richer inference, including numerical reasoning. The existing generation studies exploring numerical data still pointed out major logical errors in their generated text due to the limitation of language models in handling numeric operations. Therefore, we propose solving this issue by using not only explicit facts mentioned in table contents as our inputs but also inferring facts derived after reasoning. Focusing on numerical reasoning, we obtain inferred facts as pre-executed arithmetic operation results by doing arithmetic operations over tables in advance. In supporting arithmetic operations over tables, we note that aggregating and comparing numbers with different metric-types will result in inaccurate analysis. Therefore, we propose a metric-type identification framework that automatically derives the metric-type from tables with unknown schemas. In end-to-end settings, the predicted metric-type can be utilized for calculation over tables to obtain pre-executed arithmetic operation results, which are used as additional inputs by our proposed generation framework to enhance the model's reasoning ability while producing analytical text.

Chapter 2 describes the work related to two subtasks in this study, metric-type identification for numerical tables and table-to-text generation with numerical reasoning.

Chapter 3 describes the process of creating a numerical table-to-text dataset and a detailed comparison with related datasets. We automatically extracted tables from PDF files of scientific papers in the computational linguistics domain and kept only numerical tables related to experimental results. Then, we collected candidates for corresponding descriptions from the source files by using table numbers in their captions as keywords for the collection. These table descriptions are naturally produced by experts with richer inference.

Chapter 4 describes our proposed framework for metric-type identification from numerical tables with unknown schema. We propose a joint framework of metric-type location prediction and metric-type token generation to handle both in-header and out-of-header metric-type identification problems. As the first model, we adopt a pointer-generator to generate metric-type tokens, combined with a softmax layer to predict the metric-type location. Because our annotated dataset is limited, we propose transfer learning as the second model by fine-tuning available pretrained models trained on a large corpus in our task. We used BERT, a pretrained model with bi-directional transformer encoders, to take advantage of its ability in producing more contexts from two directions. We also fine-tuned a pretrained encoder-decoder T5, which successfully solved multitask NLP problems with its unified framework.

Chapter 5 describes our proposed framework for table-to-text generation with numerical reasoning. We address the table-to-text generation problem not only by conditioning facts that are explicitly mentioned in tables but also facts that are inferred from table contents. These inferred facts are derived after arithmetic operations over tables as pre-executed operation results. We propose feeding both explicit and inferred facts to generation models in order to extend their ability in generating richer inference texts. We conduct experiments with fine-tuned pretrained models by using several types of table linearization as input representations in a comparison with a template-based generator and pointer-generator. The experiments showed that transfer learning of pretrained language models lead to an improvement in our settings, which resulted in more fluent text, while there was still a lack of fidelity to table contents. We then propose incorporating a copy mechanism by using general placeholders to avoid the production of hallucinated phrases that are not supported by tables while preserving high fluency. Even though our proposed copy mechanism failed to learn to generate better outputs in the decoder-only pretrained models, we showed that a copy-based pretrained model with an encoder-decoder architecture leads to a better BLEU score and improves correctness.

Chapter 6 describes the conclusions, limitations, and future work of this thesis. We propose a framework consisting of a pre-trained model and a copy mechanism for table-to-text generation. The pre-trained models are fine-tuned to produce fluent text enriched with numerical reasoning by feeding both explicit and inferred facts derived from table analysis results as our inputs. However, the generated text still lacks fidelity to the table contents. The copy mechanism is incorporated in the fine-tuning step by using placeholder alignments to avoid generating hallucinated phrases that are not supported by a table while preserving high fluency. As limitation, our approach to placeholder alignments in copy-based models still uses rigid slot filling, which is prone to grammatical errors. Designing better copy mechanism approaches for transfer learning using pretrained models would be an interesting line of future work.