Miraico

AI Medical Coding Assistant
Technical Overview

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Overview

Medical coding is an important operation within the healthcare industry's revenue cycle management process, critical to the care of patients, efficiency of payments, and integrity of operations. It is also a time-consuming and error-prone manual operation that has only recently started to adopt computer-aided automation. However, medical records present several unique challenges to current automation techniques that use rule-based algorithms and even advanced natural language processing techniques. Miraico, the AI coding assistant developed by ASUS, utilizes a multi-prong approach to achieve clinical understanding of medical records and recommend relevant ICD-10 codes with efficiency and a high degree of accuracy.

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Benefits of Computer-Assisted Medical Coding

Medical coding is mostly done by specialized individuals and certificated medical coders who examine and translate medical records and clinical documentation into medical codes such as ICD-10 to create insurance claims for patients. Although healthcare organizations continue to improve and optimize their billing and coding operations, yet many challenges still exist as the operation itself is largely manual. These challenges include low productivity due to complex medical records, high turnover caused by demanding workload, difficulty hiring because of the need for specialization, and loss of revenue as a result of backlog and errors in coding outputs.

Computer-assisted coding (CAC), software that uses a combination of rule-based algorithms and natural language processing-based artificial intelligence has emerged to help hospitals' medical records and health information management offices streamline their coding workflow, improve ICD-10 coding consistency, and enable higher ROI with more accurate DRG assignments.

Challenges of Current Solutions

In order for CAC software to realize its promise of assisting coding professionals and transforming coding operations, there are technical challenges that need to be overcome.

Shortcomings in Medical Domain Natural Language Understanding

ICD-10 has approximately 140 thousand codes (CM and PCS), providing detailed information about diagnoses or procedures. However, this long-tailed taxonomy is challenging for AI models to learn as the subtle changes in the text may refer to different ICD-10 codes. Existing approaches suffer from inaccurate ICD-10 code prediction due to insufficient understanding of clinical terms and the semantic behind each ICD-10 code. Furthermore, in a medical record, only part of spans are relevant for predicting an ICD code. Without a mechanism to extract relevant words and context from a medical record, AI's recommendations may be negatively impacted by irrelevant texts.

Word embedding is crucial for NLU tasks as it is used to represent words for analyzing semantics between words. Although there are some well-established word embedding methods such as Word2Vec and BERT (Bidirectional Encoder Representations from Transformers), none of them can be effectively and efficiently adopted into production without sophisticated adjustments when dealing with unstructured natural language texts in the medical domain.

For example, Word2vec learns word embeddings of a word by its context from a large corpus of text. As a result, each word in the vocabulary set will have its own vector representation, which can be easily applied to many NLP tasks. However, there are some drawbacks.

[1] BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding

Inability to handle unknown (out-of-vocabulary, OOV) words

Any model that is pre-trained on a fixed vocabulary set will not be able to represent words that are not in its vocabulary. There are many domain-specific words and variations of medical terms that may not appear in the corpus during pre-training, also misspellings and abbreviations are often observed in medical records, causing severe OOV issues.

Inability to disambiguate various senses of polysemous words

Since each word is only trained to a single vector, the resulting model is unable to distinguish different meanings of the same word. Ambiguous words are common in medical records. For example, "cold" has several possible meanings in the Unified Medical Language System (UMLS) Metathesaurus including "common cold", "cold sensation" and "cold temperature". Lack of proper word disambiguation may be imprecise for representing words in different contexts and therefore harms performance in the downstream tasks.

The Miraico Approach to AI Coding

Miraico ICD-10 AI Coding Assistant uses a multi-prong approach to analyze and understand the clinical narratives of medical records, and automatically recommends the most relevant and accurate ICD-10 code reliably. Specifically, the approach uses ALFER-BERT, a custom language model to process long and unstructured medical records to contextualized learning, and Clinical Intelligence Attention, an unique intelligence extraction technique to interpret medical records and classify ICD-10 codes.

Figure 1 - Multi-prong AI-Assisted Coding Process

1 - ALFER-BERT - Language Model for Medical Records

Medical-specific corpus and vocabularies

Miraico's ALFER-BERT (Attention on Length Free Electronic Health Records-BERT) is a NLU model that was designed specifically to analyze medical records. It is derived from BERT, leveraging its mechanics of using Transformer to learn contextual information between sub-words. Even though BERT's WordPiece addresses OOV issues by combining sub-words to understand uncommon vocabularies, this solution does not always accurately interpret the clinical meaning of medical terms. In order to develop an AI model that truly understands, statistical analyses were applied on tens and millions of real-world health records and generated a set of affixes that is best at representing and constructing clinical vocabularies.

SNOMED to ICD Representation

Generally speaking, it is very common for clinicians to use different clinical terms to describe the same disease. For example, heart attack, heart infarction, myocardial infarction (MI) could be used by different clinicians to describe the same condition across multiple medical records. For a trained expert in the healthcare domain, this is a non-issue. However, for a machine learning model, these are distinct vocabularies that would significantly dilute the training data points and greatly lower its recall rate.

To address this challenge, SNOMED's comprehensive collection of clinical terminology was used to determine synonymy and relevancy among the universe of medical terms. A deep learning model was then used to map that output to the corresponding ICD-10 codes. This representation enables the Miraico AI Coding Assistant to interpret diagnoses more in line with a domain expert instead of a keyword-based algorithm, improving its ability to analyze and interpret medical records compiled by different clinicians with different preferences with more consistency.

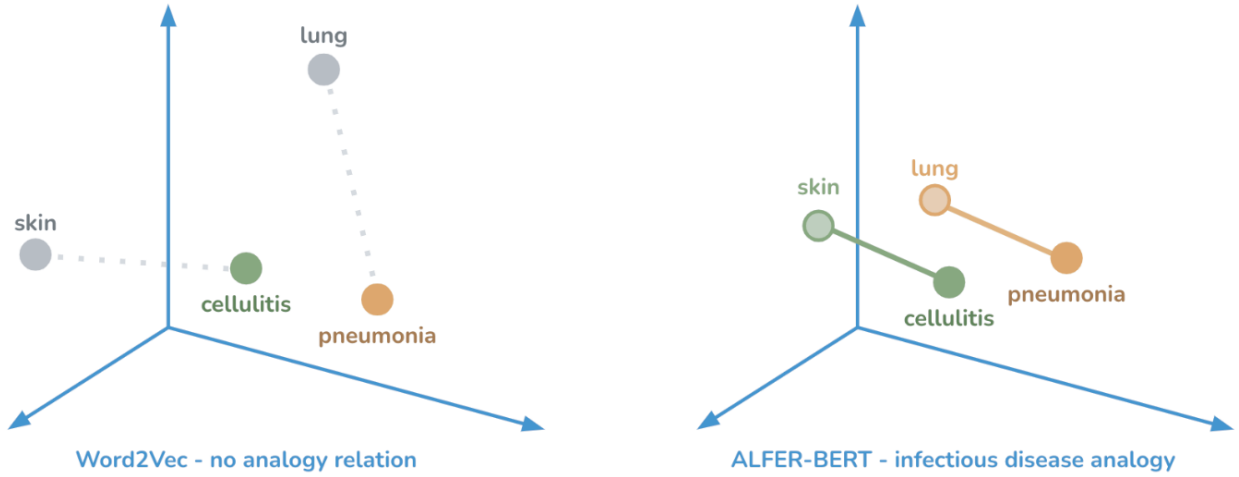

Figure 2 - word representations between generic language model (Word2Vec, no medical analogy relation) and custom medical language model (miraico ALFER-BERT, infectious disease analogy relation)

Architecture for real-world deployment

Because the BERT model uses a large number of parameters, it requires large computing power to conduct predictions with a reasonable inference time. This might be a non-issue for research-oriented projects, but for deployments supporting real-world coding operations, providers are often faced with a tradeoff between speed and performance.

A lighter-weight model was re-architected from BERT by reducing the transformer layers that had the largest impact on model inference time but posed minimal impact on performance. Knowledge distillation was also employed to transfer knowledge from the original BERT model to a smaller one with minimal loss of validity. The end result is a highly efficient predictive model with much fewer parameters but optimized for both speed and performance.

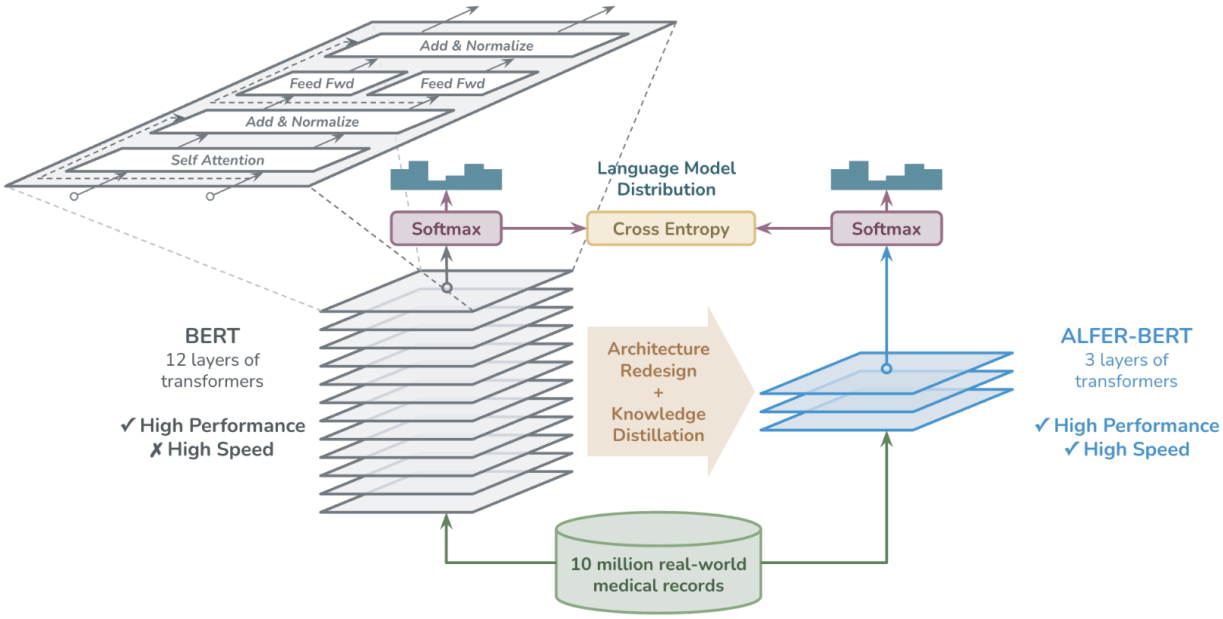

Figure 3 - ALFER-BERT architecture (reduced transformer layers and knowledge distilled), optimized for deployment

Property	BERT	BioBERT	ALFER-BERT
Corpus	Wiki + Books	Wiki + Books + Pubmed	10M RWD Medical Records
Vocabulary	General Domain	General Domain	Medical Domain
Benchmark	-	MIMIC (ICD-9): F1 56% Hospital EMR (ICD-10): F1 ~60%	MIMIC (ICD9): F1 59% Hospital EMR (ICD10): F1 ~80%
Architecture	BERT-base-cased	Bert-base-cased	Custom DistilBERT
Parameters	110M	110M	24M

2 - Clinical Intelligence Attention - Knowledge Extraction Technique

Very often, the information recorded in a medical record will contain descriptions of many different diseases. If a machine learning model is not able to extract the clinical understanding and aggregate the clinical insights related to their respective diseases, they will become noise to one another, negatively impacting the overall performance of the predictive model.

Miraico's Clinical Intelligence Attention automatically establishes a relationship between different clinical insights and ICD-10 codes during the model training process. This allows the resulting model to emphasize relevant insights as usable data for any given ICD-10 it is considering, raising the performance of the final recommendation.

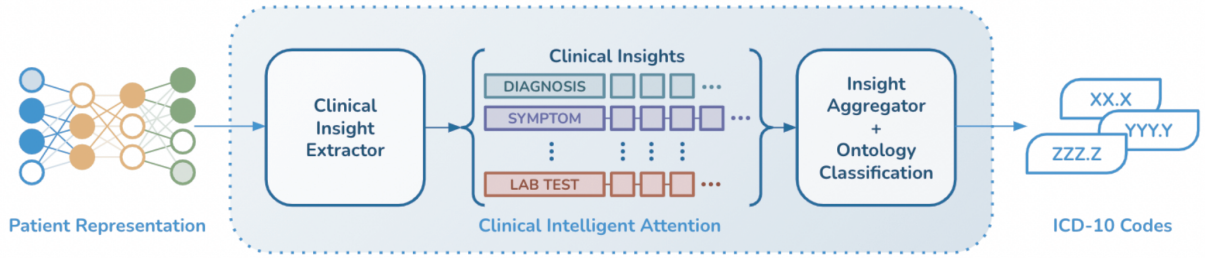

Figure 4 - Clinical Intelligent Attention - extract, aggregate, classify

Clinical Intelligence Attention also enables explainable AI, a way for users to understand and interpret predictions made by the machine learning model. For each recommended code, the clinicians and coders are able to quickly identify the relevant description and its assigned weighting to verify the validity of the AI prediction.

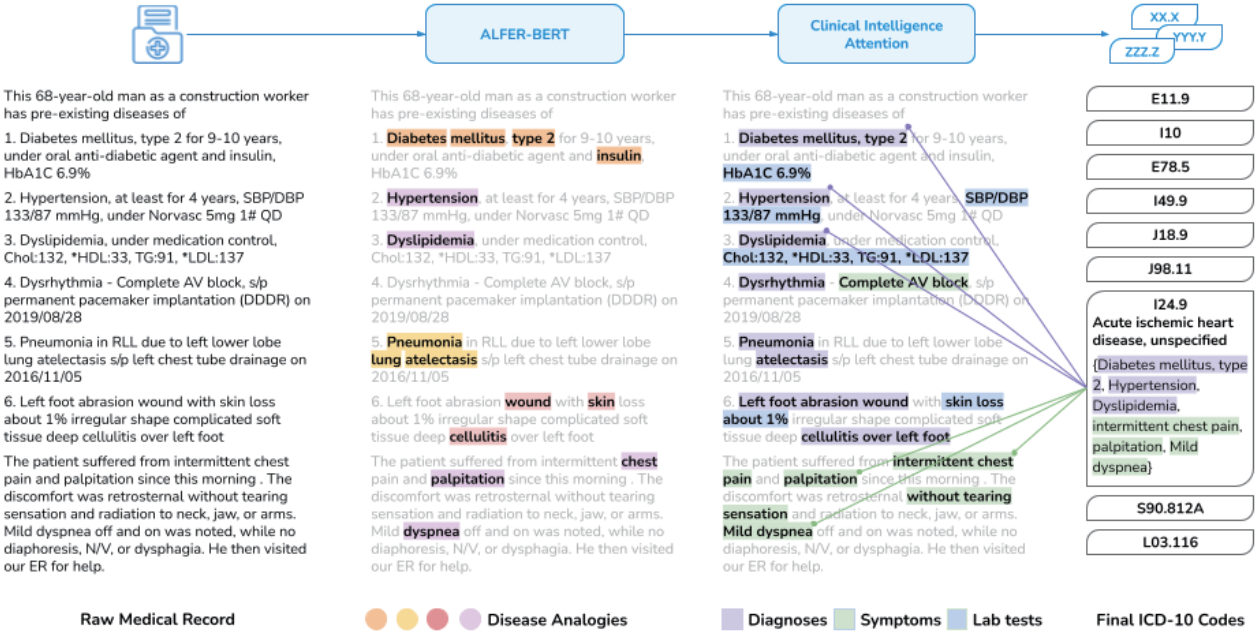

Figure 5 - An example showing how Miraico's multi-prong approach would analyze a medical record and recommend codes that would be missed by traditional language models

Results

Miraico's multi-prong approach has yielded positive results and generated tangible value for several partnering healthcare organizations.

Improved medical coding efficiency and accuracy

Organizations that have augmented their manual coding operation with Miraico's AI-powered recommendations have seen significant improvement with coding accuracies. Miraico's continuous training mechanism learns from every manual revision, allowing the solution to further improve its performance over time.

Improved case mix index and potential revenue

Using Miraico consistently has also helped organizations improve their case mix index by increasing the usage of specific codes over generic codes and CC capture rate. This has enabled a more efficient operation by providing administrators with a more accurate view of resource allocation and quality of care. Improvement to the case mix index also directly impacts the potential revenue not only for a particular procedure but also for the entire hospital.

Improved hospital operation and budget planning

Organizations that utilize Miraico during hospitalization, as early as admission, have been able to better estimate costs of care based on Miraico's predicted ICD-10 codes. This information has been used to streamline operations, optimize patient experience, and plan budgets more effectively.

About Miraico

Miraico is developed by ASUS Intelligent Cloud Services Center (AICS), the AI software division of ASUS with a mission to empower businesses with powerful AI technologies. Miraico is powered by cutting-edge Natural Language Understanding (NLU) technology and can intelligently understand and automatically recommend ICD-10 codes by analyzing free-text medical records. Its user-friendly design integrates seamlessly with existing workflows, thereby improving coding efficiency and optimizing hospital reimbursements.

About AICS - The Team Behind Miraico

ASUS Intelligent Cloud Services Center (AICS) is the AI software division of ASUS. Its mission is to empower businesses through leading-edge AI technologies. Miraico is one of a wide range of Medical AI solutions that AICS has developed to empower healthcare professionals and medical institutions to make data-driven decisions, improve the quality of patient care, and increase overall operational efficiency. Other AI-based medical software services developed by AICS include an EMR search application, a clinical decision support service platform, and a drug safety service.

For inquiries about partnerships, please visit: https://aics.asus.com/contact-en/