Retrieve, Reason, and Refine: Generating Accurate and Faithful Patient Instructions

Fenglin Liu[1], Bang Yang[2], Chenyu You[3], Xian Wu[4], Shen Ge[4], Zhangdaihong Liu[1,5], Xu Sun[2], Yang Yang[6], David A. Clifton[1,5]

[1] University of Oxford,
[2] Peking University, [3] Yale University, [4] Tencent JARVIS Lab,
[5] Oxford-Suzhou Centre for Advanced Research, [6] Shanghai Jiao Tong University School of Medicine

Introduction

Input (Patient's Health Records)

Admission Notes | Nursing Notes | Radiology Notes | Physician Notes | ... ... | Medications

Output (Patient Instruction)

Patient 1: Please shower daily including washing incisions gently with mild soap, no baths or swimming, […] please no lotions, cream, powder, or ointments to incisions […] females: please wear bra to reduce pulling on incision, avoid rubbing on lower edge.

Patient 2: You were admitted for bleeding from an ulcer in your stomach. This ulcer is at least partially caused by naproxen. You should stop taking naproxen and take only tylenol for pain. […] you are scheduled to get a repeat endoscopy next week. Prior to the procedure do not have anything to drink or eat after midnight.

Figure 1. Two examples of the Patient Instruction (PI) written by physicians which guide the patients how to manage their conditions after discharge based on their health records during hospitalization.

Background:

➤ The "Patient Instruction" which contains critical instructional information provided both to carers and to the patient at the time of discharge, is essential for the patient to manage their condition outside hospital.

➤ An accurate and easy-to-follow PI can improve the self-management of patients which can in turn reduce hospital readmission rates.

Limitation & Challenge:

➤ However, writing an appropriate PI is a necessary but time-consuming task for physicians, exacerbating the workload of clinicians who would otherwise focus on patient care.

➤ Besides, physicians need to read lots of patient's health records in their daily work, resulting in substantial opportunity for incompleteness or inappropriateness of wording.

We propose a task that provides an objective means of avoiding incompleteness, while reducing clinical workload: the generation of the PI, which is imagined as being a document that the clinician can review, modify, and approve as necessary (rather than taking the human "out of the loop").

Approach

We build a benchmark clinical dataset and propose the Re³Writer. It imitates the working patterns of physicians to first **retrieve** related working experience from historical PIs written by physicians, then **reason** related medical knowledge. Finally, it **refines** the retrieved working experience and reasoned medical knowledge to extract useful information, which is used to generate the PI for previously-unseen patient according to their health records during hospitalization.
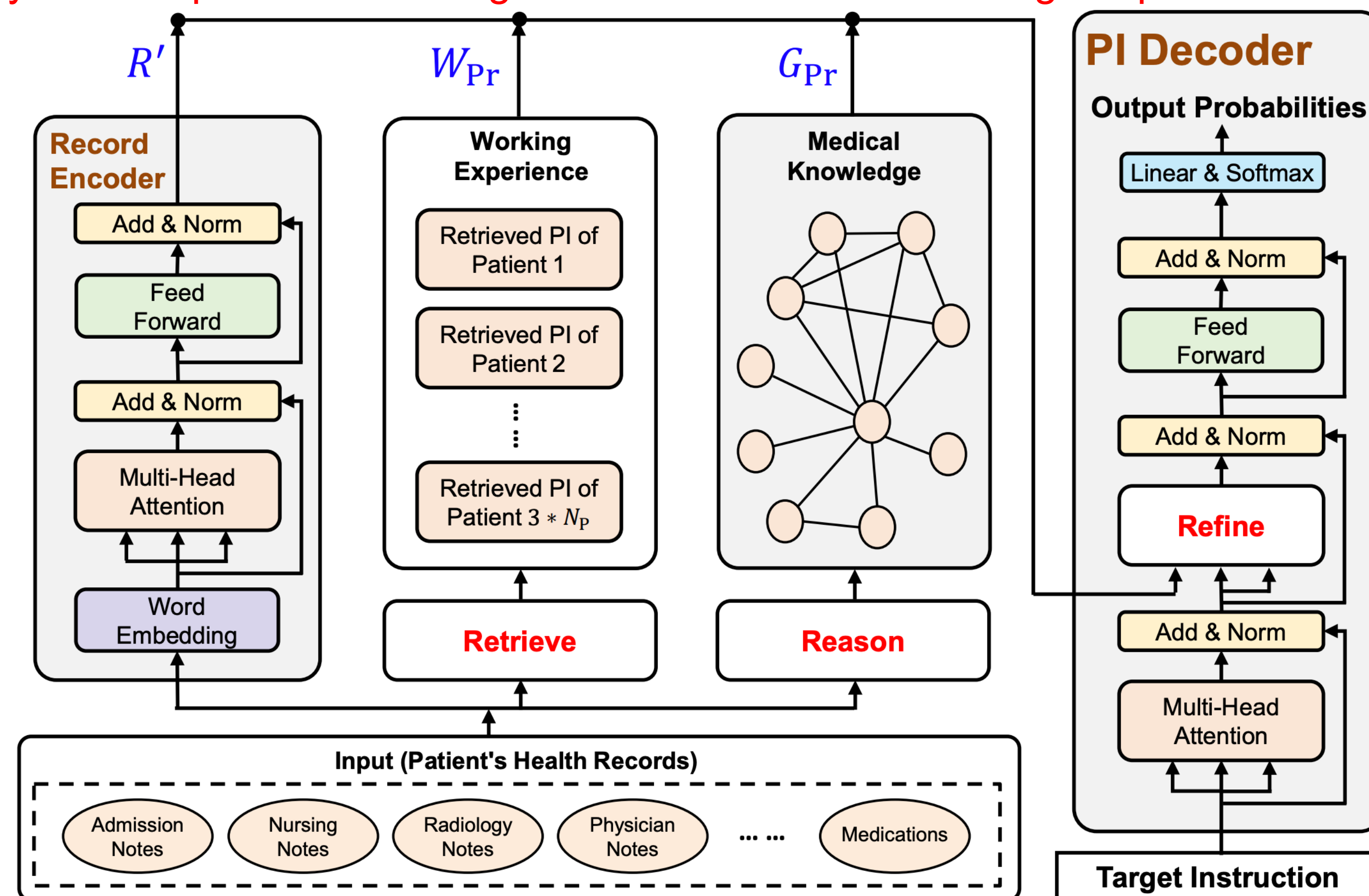
Retrieve:

➤ We first extract the one-hot embeddings of all clinical codes. Given a new patient, we represent this patient's hospitalization by averaging the associated one-hot embeddings of clinical codes produced during this hospitalization. Then, we collect a set of patients similar (cosine similarity) to the new patient according to the associated clinical codes.

Reason:

➤ We consider the clinical codes as nodes. The weights of the edges are calculated by normalizing the co-occurrence of pairs of nodes in the training corpus.

Refine:

➤ The PI generation task aims to produce a PI based on the source patient's health records, supported with appropriate retrieved working experience and reasoned medical knowledge.

Experiments

➤ We evaluate our approach on our built PI dataset, which is curated from the MIMIC-III v1.4 resource [2].

| Methods	METEOR	ROUGE-1	ROUGE-2	ROUGE-L	BLEU-1	BLEU-2	BLEU-3	BLEU-4
LSTM [5]	16.5	35.9	17.9	33.2	34.4	26.3	23.1	21.0
with Re³Writer	19.6 (+3.1)	39.4 (+3.5)	20.5 (+2.6)	37.0 (+3.8)	40.8 (+6.4)	31.5 (+5.2)	27.6 (+4.5)	25.3 (+4.3)
Seq2Seq [2]	19.9	39.0	20.3	37.1	41.6	32.5	27.9	25.1
with Re³Writer	20.9 (+1.0)	40.8 (+1.8)	21.9 (+1.6)	38.6 (+1.5)	43.2 (+1.6)	34.2 (+1.7)	29.7 (+1.8)	26.8 (+1.7)
HRNN [28]	20.3	40.1	20.5	36.9	43.5	33.7	28.8	25.6
with Re³Writer	21.6 (+1.3)	42.5 (+2.4)	22.1 (+1.6)	39.0 (+2.1)	47.2 (+3.7)	36.9 (+3.2)	31.5 (+2.7)	27.8 (+2.2)
CopyNet [12]	19.5	38.3	19.9	36.5	40.4	31.6	27.0	24.4
with Re³Writer	20.6 (+1.1)	39.9 (+1.6)	20.9 (+1.0)	37.8 (+1.3)	42.7 (+2.3)	33.6 (+2.0)	28.7 (+1.7)	26.0 (+1.6)
Transformer [50]	21.8	42.1	21.6	38.9	47.1	36.8	31.4	27.3
with Re³Writer	23.7 (+1.9)	45.8 (+3.7)	24.4 (+2.8)	42.2 (+3.3)	52.4 (+5.3)	41.2 (+4.4)	35.0 (+3.6)	30.5 (+3.2)

Dataset: Patient Instruction (PI)

Table 1. Performance on the PI dataset. Higher is better in all columns.

Ground Truth: dear ms. [name], you were admitted to the hospital with abdominal pain, nausea, vomiting and inability to eat. you were diagnosed with a urinary tract infection, and treated with antibiotics. your pain did not improve, and you were diagnosed with chronic cholecystitis (inflammation of your gallbladder). your gallbladder was removed. changes to your home medications include: for pain, you can take acetaminophen. you can also take oxycodone 5 - 10mg every 4 - 6 hours for pain. your pain should be improving, so you should require less medication over time.

Retrieved Working Experience
1. […] the fevers and urinary tract infection were treated with antibiotics […]
2. […] you will also be prescribed an antibiotic for your urinary tract infection […]
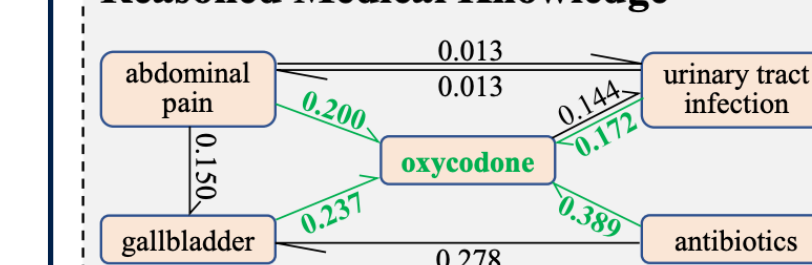
Baseline: dear ms. [name], it was a pleasure taking care of you at [hospital]. you were admitted to the hospital for abdominal pain and nausea / vomiting. you were found to have an infection in your blood stream which we treated with antibiotics. you were also started on iv antibiotics for this infection. you will need to follow - up with dr. [name] as listed below.

Reasoned Medical Knowledge

with Re³Writer: dear ms. [name], it was a pleasure taking care of you at [hospital]. you were admitted to the hospital with abdominal pain and found to have an infection in your gallbladder. you were treated with antibiotics for this infection. you also had a urinary tract infection which was treated with antibiotics. we made the following changes to your medications : - start oxycodone 5 mg every 6 hours as needed for pain.

Figure 3. An example of the PI generated by baseline and Re³Writer. Underlined: alignment between the ground truth text and the generated text. Red: unfavorable results. When generating corresponding text, Blue: working experience, Green: medical knowledge.
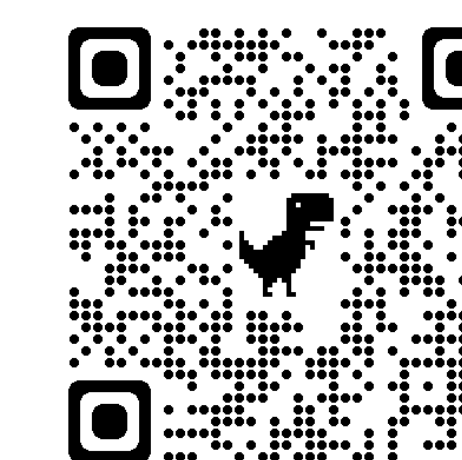
➤ Our approach not only consistently boosts the performance across all metrics for a wide range of baseline models with substantially different model structures, but also generates meaningful and desirable PIs regarded by clinicians.
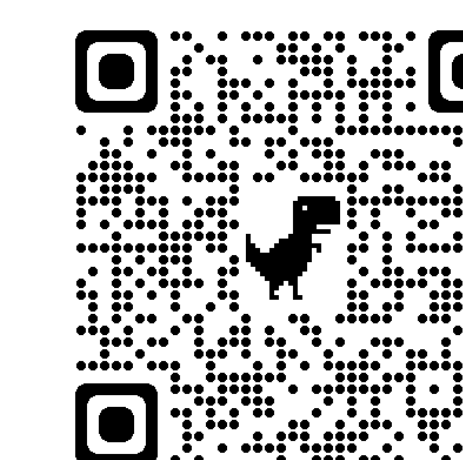
References

[1] Attention is all you need. *In NIPS*, 2017.
[2] MIMIC-III, a freely accessible critical care database. *Scientific Data*, 3, 2016.

Contact Us

● fenglin.liu@eng.ox.ac.uk
● bangyang@pku.edu.cn
● chenyu.you@yale.edu
● david.clifton@eng.ox.ac.uk

➤ paper   ➤ code