AI for COVID-19: An online virtual care approach

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http://www.curai.com

COVID-19 and AI Virtual Conference
Stanford 04/01/2020
AI-powered virtual care for everyone
Healthcare access and scalability

- >50% world with no access to essential health services
  - ~30% of US adults under-insured
- ~15 min. to capture information, diagnose, recommend treatment
- ⅓ of Americans self-diagnose online

New Findings Confirm Predictions on Physician Shortage

The United States will see a significant demand for physicians. A new data published today by the American Medical Association shows that the projected shortage of physicians by 2030 ranges from 65,000 to 127,000 physicians.

Coronavirus Is Exposing Deficiencies in U.S. Health Care

Virtually Perfect? Telemedicine for Covid-19

Judd E. Hollander, M.D., and Brendan G. Carr, M.D.
Towards AI powered scalable health systems

- **Mobile-First Care**, always on, accessible, affordable
- **AI + human providers in the loop** for quality care
- **Always-Learning** system
- **AI to operate in-the-wild**
How does this look like?
Our approach to COVID-19

- Potential COVID patient
  - AI Q & A
  - Assessment (history taking + triage)
  - At-home testing
  - Care Plan
  - Follow-up

- EHR
Coronavirus
We're here to help
The spread of novel coronavirus (COVID-19) is a challenge for our global community. Our care team is here to help with your concerns, and we will provide at-home testing shortly (available in California only).
If you are concerned about your symptoms, take our assessment and sign up to be notified when a test is available.

Start assessment

Coronavirus updates
Last updated: March 25, 2020 @ 10:34 AM PST

General information
What is the coronavirus? +
What are the symptoms? +

Assessment
Do you have a cough?
Yes  No

Do you have a fever?
Yes  No

Are you experiencing shortness of breath?
Yes  No

Is your shortness of breath:
☑ with activity
☐ at rest

Do you have associated chest pain?
Yes  No

Do you have a sore throat?
Yes  No

Assessment
Are you a healthcare worker?
Yes  No

Have you interacted with any patients with confirmed COVID-19 while not using any personal protective equipment?
Yes  No

In which zip code do you live?
We use this information to determine your exposure risk based on where you live and the latest data on local COVID-19 infections. We do not use this information for anything else.
94035
AI + Providers in the loop + Daily follow up

**Assessment results**

**Infection risk**
Based on the information you provided, you have a high likelihood of novel coronavirus (COVID-19) infection at this time. It is likely that you were exposed to the virus and you have symptoms that are commonly seen with COVID-19.

**Testing**
We recommend you be tested for COVID-19. We don't have testing available yet, but we will let you know as soon as it is available.

**Recommendations**
Our doctors can help you understand your symptoms, infection risk, and recommended next steps. Please start a visit below.

Going forward:
- Stay home except for essential needs

**Sign up**

**Retake assessment**

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**Messages**

Good morning, I'm Dr. Rios, a board certified physician and I'm going to be working with you today. I have reviewed the information you have shared. To be thorough, is there any more information you'd like to share with me?

Hi Dr. Rios. This whole situation has me a bit anxious to be honest. I think I just have a cold, but how do I know?

Unfortunately it's hard to tell because mild symptoms of the coronavirus are similar to the common cold or flu. The only way to know for sure is to get you tested.

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**Follow-up clinical risk**

Have your symptoms changed?
- Fever
  - Gone away
  - Better
  - Same
  - Worse

- Cough
  - Gone away
  - Better
  - Same
  - Worse

- Shortness of breath
  - Gone away
  - Better
  - Same
  - Worse

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Do you have any other questions for me?

Not right now. Thank you so much!!!

My pleasure. We are here whenever you need us. Here is a summary of what we discussed:

Care plan for Concern for COVID-19 (Concern for Coronavirus Disease 2019)
- Acetaminophen 500mg every 6 hours as needed for fever
- COVID-19 swab test ordered
- Rest and sleep!
Working on...

- Added at-home testing capabilities to our platform, waiting for FDA to approve
- In discussions with existing health systems who may use platform to scale and improve access
Open Set Medical Diagnosis

Viraj Prabhu1,2,3 Anitha Kannan4 Geoffrey J. Tso5 Namit Kataria6 Manish Chahal5 David Sontag5,1 Xavier Amatriain5
1Georgia Tech 2MIT 3Curai

Abstract

Machine-learned diagnosis models have shown promise as medical aids but are trained under a closed-set assumption, i.e. that models will only encounter conditions on which they have been trained. However, it is practically infeasible to obtain sufficient training data for every human condition, and once deployed such models will invariably face previously unseen conditions. We frame machine-learned diagnosis as an open-set learning problem, and study how state-of-the-art approaches compare. Further, we extend our study to a setting where training data is distributed across several healthcare sites that do not allow data pooling, and experiment with different strategies of building open-set diagnostic ensembles. Across both settings, we observe consistent gains from explicitly modeling unseen conditions, but find the optimal training strategy to vary across settings.

ProtoTypical Clustering Networks for Dermatological Disease Diagnosis

Viraj Prabhu1,2,3 Anitha Kannan4 Murali Ravuri5 Manish Chahal5 David Sontag5,1 Xavier Amatriain5
1Georgia Tech 2MIT 3Curai

Abstract

We consider the problem of image classification for the purpose of aiding doctors in dermatological diagnosis. Dermatological diagnosis poses two major challenges for standard off-the-shelf techniques: First, the data distribution is typically extremely long tailed. Second, intra-class variance is often large. To address the first issue, we formulate the problem as two-shot learning, where once确诊 in online services and telemedicine for closing the gap of healthcare access, these services also face similar problems [28]. The need to find effective solutions to aid doctors in accurate diagnosis motivates this work.

Learning from the experts: From expert systems to machine-learned diagnosis models

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Abstract

Expert diagnostic support systems have been extensively studied. The practical applications of these systems in real-world scenarios have been somewhat limited due to well-understood shortcomings, such as lack of extensibility. More recently, machine-learned models for medical diagnosis have gained momentum, since they can learn and generalize patterns found in very large datasets like electronic health records. These models also have shortcomings—in particular, there is no easy way to incorporate prior knowledge from existing literature or experts. In this paper, we present a method to merge both approaches by using expert systems as generative models that create simulated data on which models can be learned. We demonstrate that such a learned model not only preserves the original properties of the expert systems but also addresses some of their limitations. Furthermore, we show how this approach can also be used as the starting point to combine expert knowledge with knowledge extracted from other data sources, such as electronic health records.

Classification as Decoder: Trading Flexibility for Control in Medical Dialogue

Saer Miliecer1 Anitha Kannan4 Manish Chahal5 Xavier Amatriain5
1Stanford 2Curai

Abstract

Generative seq2seq dialogue systems are trained to predict the next word in dialogues that have already occurred. They can learn large statistically consistent domains, but fail a domain adaptation of contextualized content, and generate a wide variety of responses. This flexibility comes at the cost of control, a requirement for a richer dialogue control. In this paper, we present a method to trade-off between flexibility and control by using expert systems as generative models. The experts are encoders, and the output of the training data will be reproduced by the model at inference time. We make a small amount of encoding effort and sacrifice of response variety in exchange for quality control. More specifically, a pretrained language model encodes the conversational context, and we parameterize a classification head to map an encoded conversational context to a response class, where each class is a nichely labeled group of interchangeable responses. Experts can replace these response examples over time as new practices change without retraining the classifier or invalidating old training data. Expert evaluation of 773 source discourse/patient combinations showed that only 12% of the discrimination model’s responses are worse than the what the doctor ended up saying, compared to 15% for the generative model.

Domain- Relevant Embeddings for Medical Question Similarity

Clara T. McCoy2,1 Namit Kataria5 Anitha Kannan4 Xavier Amatriain5
1Stanford 2Curai

Abstract

The use of clinical questions are asked online for exceeds the capacity of qualified people to answer them, and many of these questions are not unique. Identifying questions pairs could reduce questions in the most answerable discourse. Previous work on cross-domain similarity for non-approximated applications, these approaches do not generalize well to the medical domain, where medical inquiry is often required to determine semantic similarity. In this paper, we show how to use supervised approach of pre-training a siamese network on medical question–answer pairs is a particularly useful information retrieval for the clinical path of determining medical question and links. While other existing link (CRediT) classification of human disease1 estimates more than 1000 skin or skin-related illnesses. Moreover, most surge in online services and telemedicine for closing the gap of healthcare access, these services also face similar problems [28]. The need to find effective solutions to aid doctors in accurate diagnosis motivates this work.

The accuracy vs. coverage trade-off in patient-facing diagnosis models

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Abstract A third of adults in America use the Internet to diagnose medical concerns, and online symptom checkers are increasingly part of this process. These tools are powered by diagnosis models similar to clinical decision support systems, with the primary difference being the coverage of symptoms and diagnoses. To be useful to patients and physicians, these models must have high accuracy while covering a meaningful space of symptoms and diagnoses. To the best of our knowledge, this paper is the first in studying the trade-off between the coverage of the model and its performance for diagnosis. To this end, we learn diagnosis models with different coverage from EHR data. We find a 1% drop in top-1 accuracy for every 10 diagnoses added to the coverage. We also observe that complexity for these models does not affect performance, with linear models performing as well as neural networks.
Question similarity

- Transfer learning
- Double-finetune BERT model
  - Handle data sparsity
  - Medical domain knowledge through an intermediate QA binary task
- Out-of-the-box applied to COVID specific Q/A
## Automated Question/Answering

- Automated question answering via question similarity
- Practitioners’ vetted answers with ability to follow up

<table>
<thead>
<tr>
<th>User Questions</th>
<th>Matching Questions in our FAQ (Answer not shown here for brevity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When do COVID symptoms start after exposure?</td>
<td>How long is it between when a person is exposed to the virus and when they start showing symptoms?</td>
</tr>
<tr>
<td>I am asymptomatic and have been social distancing/self-isolating for the past x days. Can I still transmit the infection?</td>
<td>How can someone pass along coronavirus when asymptomatic? If not sneezing or coughing, how can they infect others?</td>
</tr>
<tr>
<td>Currently I’m experiencing a <strong>cough</strong> and <strong>slight chest pain</strong>. Should I just stay at home? At what point will I know I have to go to the ER?</td>
<td>When should you go to the emergency room?</td>
</tr>
</tbody>
</table>
ML + Expert systems for Dx models

Influenza 16.9
bacterial pneumonia 16.9
acute sinusitis 10.9
asthma 10.9
common cold 10.9

Influenza 0.753
bacterial pneumonia 0.205
asthma 0.017
acute sinusitis 0.008
pulmonary tuberculosis 0.007

Inputs
female
middle aged
fever
cough

Learning from the experts:
From expert systems to machine-learned diagnosis models

Murali Ravuri
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Xavier Amatriain

ML + Expert systems for Dx models

DDx with expert systems
DDx with ML model
## Feedback loop

<table>
<thead>
<tr>
<th>Inputs</th>
<th>DDx before COVID</th>
<th>DDx after COVID</th>
</tr>
</thead>
<tbody>
<tr>
<td>female middle aged fever cough nasal congestion</td>
<td>influenza 0.634 adenovirus infection 0.159 bacterial pneumonia 0.114 acute sinusitis 0.05 asthma 0.019</td>
<td>influenza 0.512 COVID-19 0.256 adenovirus infection 0.106 bacterial pneumonia 0.069 acute sinusitis 0.026</td>
</tr>
<tr>
<td>female middle aged fever cough healthcare worker</td>
<td>influenza 0.753 bacterial pneumonia 0.205 asthma 0.017 acute sinusitis 0.008 pulmonary tuberculosis 0.007</td>
<td>COVID-19 0.913 influenza 0.048 bacterial pneumonia 0.024 pulmonary tuberculosis 0.004 adenovirus infection 0.003</td>
</tr>
</tbody>
</table>
Conclusions

- Healthcare needs to scale quickly, and this has become obvious in a global pandemic like the one we are facing.
- The only way to scale healthcare while improving quality and accessibility is through technology and AI.
- AI cannot be simply “dropped” in the middle of old workflows and approaches.
  - It needs to be integrated in end-to-end medical care benefitting both patients and providers.