

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
- 1/3 of Americans self-diagnose online

PRESS RELEASES | WORKFORCE | MEDICAL EDUCATION | ADVOCACY

New Findings Confirm Predictions on Physician Shortage

APRIL 23, 2019

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The United States will see a sharp increase in demand for physicians as demand for physicians continues to grow, according to new data published today by the American Academy of Medical Colleges (AAMC). The projected shortage ranges from 46,900 to 121,900 physicians by 2030.

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shortage of **120,000 physicians** by 2030

GOVERNMENT

Coronavirus Is Exposing Deficiencies in U.S. Health Care


by David Blumenthal and Shanoor Seervai
March 10, 2020

Harvard Business Review

Summary Save Share Comment Print \$6.95 Buy Copies

Virtually Perfect? Telemedicine for Covid-19

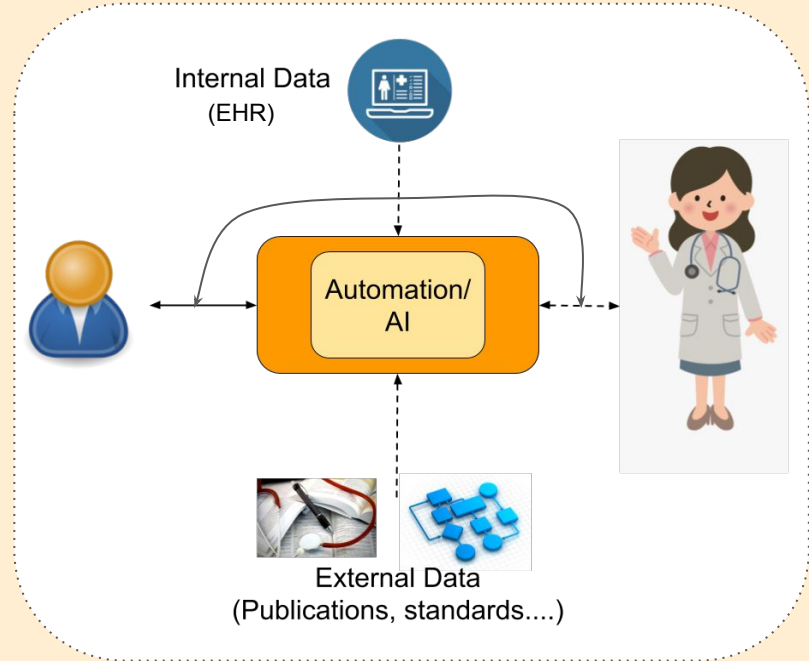
Judd E. Hollander, M.D., and Brendan G. Carr, M.D.

 The NEW ENGLAND JOURNAL of MEDICINE

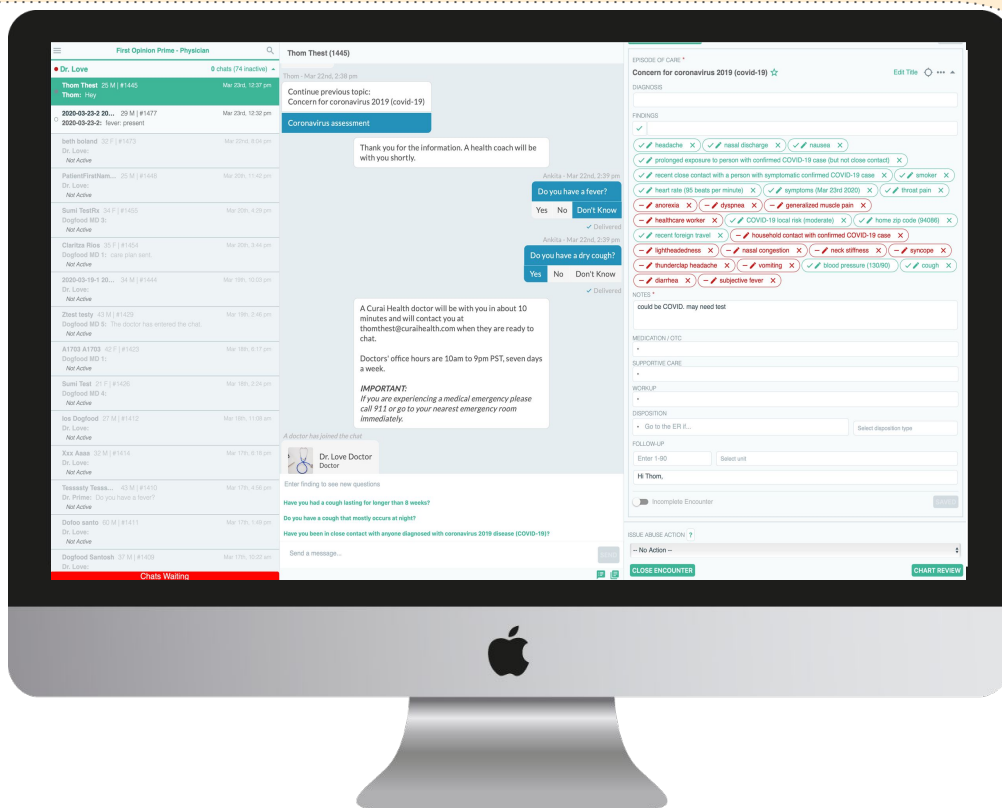
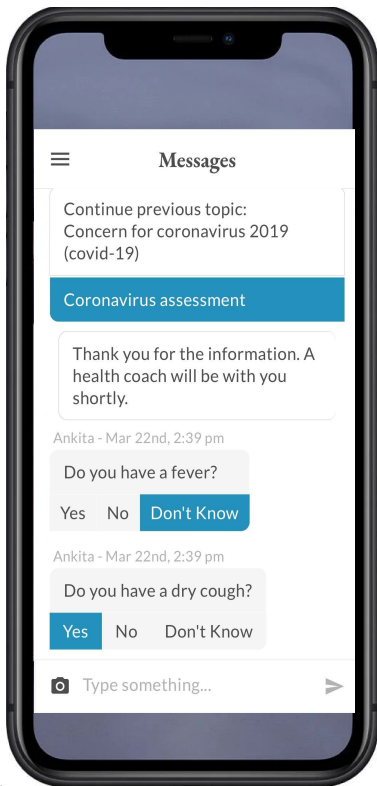


Towards AI powered scalable health systems

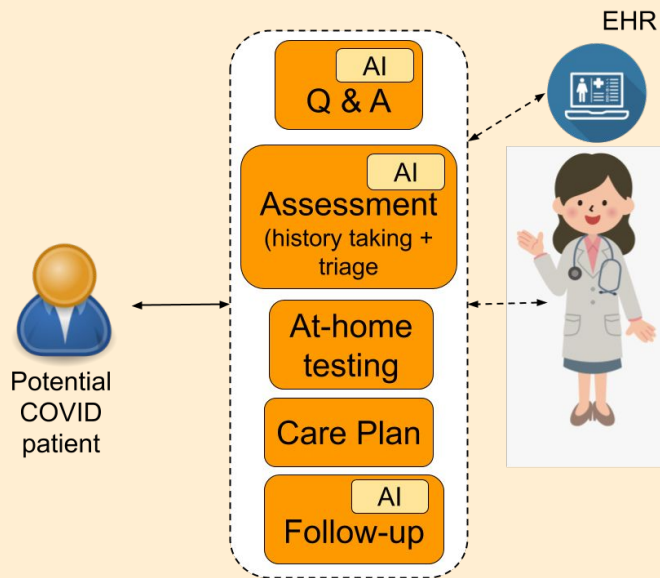
- **Mobile-First Care**, always on, accessible, affordable
- **AI + human providers in the loop** for quality care
- Always-**Learning** system
- AI to operate **in-the-wild**



How does this look like?





Our approach to COVID-19



Personalized Diagnostic Assessment





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

[→](#)

Assessment

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

Sign up

Retake assessment



Messages

Dogfood HC 4 - Mar 26th, 10:56 am

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?

Mar 26th, 11:04 am

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?

✓ Delivered

Dogfood HC 4 - Mar 26th, 11:05 am

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.



Type something...



Messages

Do you have any other questions for me?

Mar 26th, 11:21 am

Not right now. Thank you so much!!!

✓ Delivered

Dogfood HC 4 - Mar 26th, 11:22 am

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

Dogfood HC 4 - Mar 26th, 11:22 am

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!



Type something...



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



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

UnitedHealth Group Study Clears Path for Self-Administered COVID-19 Test, Improving Testing Efficiency and Protecting Health Care Workers

- Simple, scalable patient-collected COVID-19 testing process is as effective as clinician-administered test, according to study of 500 OptumCare patients
- Less-invasive testing is better tolerated by patients, reduces exposure for health care workers, and preserves personal protective equipment
- FDA has updated its guidance based on UnitedHealth Group data to allow patients to self-administer swab tests for COVID-19

Start-Ups Jump the Gun on Home Kits for Coronavirus Testing

After a federal warning, companies have stopped marketing kits that let consumers collect their own saliva or throat swabs and send them to labs.

Peer-reviewed research at Curai



Open Set Medical Diagnosis

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Abstract

Machine-learned diagnosis models have shown promise as medical aides 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.

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

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Abstract

Generative seq2seq dialogue systems are trained to predict the next word in dialogues that have already occurred. They can learn from large unlabeled conversational datasets, build a deeper understanding of conversational context, and generate a wide variety of responses. This flexibility comes at the cost of control, a concerning tradeoff in doctor/patient interactions. Inaccuracies, typos, or undesirable content in the training data will be reproduced by the model at inference time. We trade a small amount of labeling effort and some loss of response variety in exchange for quality control. More specifically, a pretrained language model encodes the conversational context, and we finetune a classification head to map an encoded conversational context to a response class, where each class is a noisily labeled group of interchangeable responses. Experts can update these exemplar responses over time as best practices change without retraining the classifier or invalidating old training data. Expert evaluation of 775 unseen doctor/patient conversations shows that only 12% of the discriminative model's responses are worse than the what the doctor ended up writing, compared to 18% for the generative model.

Prototypical Clustering Networks for Dermatological Disease Diagnosis

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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 variability is often large. To address the first issue, we formulate the problem as low-shot learning, where once de-

surge in online services and telemedicine for closing the gap of healthcare access, these services also have similar problems [20]. The need to find effective solutions to aid doctors in accurate diagnosis motivates this work.

Why is diagnosis of skin conditions hard for doctors? One important factor is the sheer number of dermatological conditions. The International Classification of Disease 10 (ICD 10) classification of human disease¹ enumerates more than 1000 skin or skin-related illnesses. However, most

Domain-Relevant Embeddings for Medical Question Similarity

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Abstract

The rate at which medical questions are asked online far exceeds the capacity of qualified people to answer them, and many of these questions are not unique. Identifying same-question pairs could enable questions to be answered more effectively. While many research efforts have focused on the problem of general question similarity for non-medical applications, these approaches do not generalize well to the medical domain, where medical expertise is often required to determine semantic similarity. In this paper, we show how a semi-supervised approach of pre-training a neural network on medical question-answer pairs is a particularly useful intermediate task for the ultimate goal of determining medical question similarity. While other pre-training tasks yield an accuracy below 78.7% on this task, our model achieves an accuracy of 82.6% with the same number of training examples, and an accuracy of 80.0% with a much smaller training set.

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

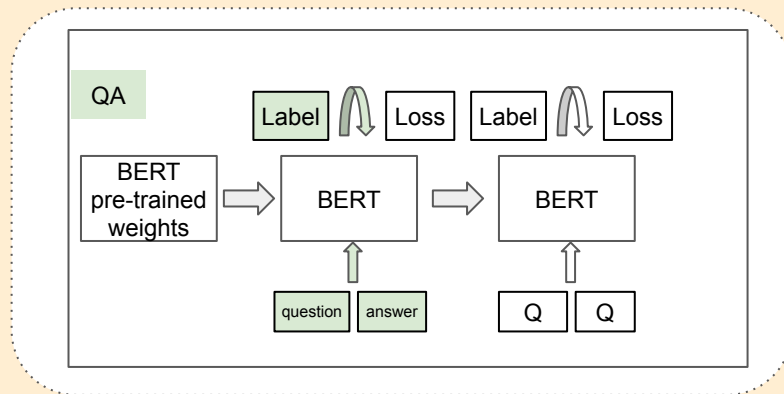
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Abstract A third of adults in America use the Internet to diagnose medical concerns, and online symptom checkers are increasingly part of this process. These tools are powered by diagnosis models similar to clinical decision support systems, with the 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-3 accuracy for every 10 diseases 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



Effective Transfer Learning for Identifying Similar Medical Questions

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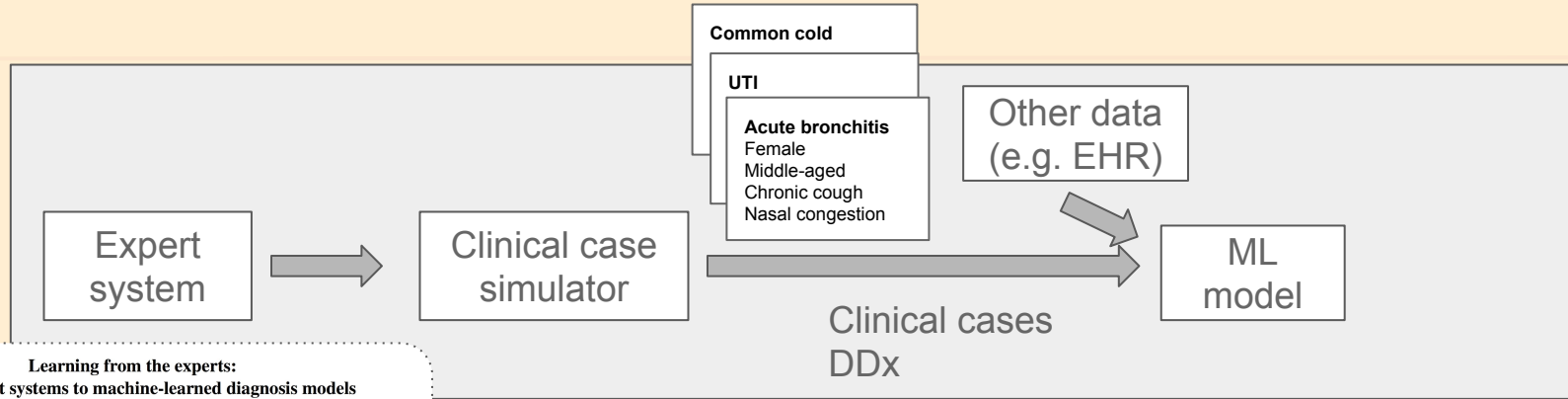
Automated Question/Answering



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

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

ML + Expert systems for Dx models



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

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DDx with expert systems

Inputs

female
middle aged
fever
cough

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

DDx with ML model

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

Feedback loop



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

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