Machine Intelligence for Human Health

A Few Noteworthy Cases

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Many machine learning solutions are effectively used in health care for detecting diseases, supporting doctors, helping patients, improving health-care processes, and saving lives. This article discusses several success stories of computing benefiting humanity in this significant application sector.

Computers and software systems are deeply changing the world. They went far beyond what science had predicted in the past century. In a few decades, computer science established itself as a new discipline, providing tools and solutions that are influencing all human activities and processes. The massive amount of big data produced every day is flooding our existence, and artificial intelligence (AI), machine learning, and pervasive decentralized computing solutions assist us daily at work and at home. Awareness of the importance and pervasiveness of the digital revolution is a primary element from which starting a path of knowledge to grasp what is happening in the world because of the information technology advancements and for understanding the appropriate approaches to face the radical changes that involve individuals and communities. For these reasons, today it is significant and useful for computer scientists and engineers to consider and discuss the societal and ethical impacts of computer science research and technology. This new column aims to provide contributions discussing how computer applications address real-world requirements and how they are transforming our society and improving human life. Topics like data governance, machine intelligence benefits, robotic systems and job market, impact of predictive algorithms, surveillance systems and applications, algorithm ethics, AI social influence, natural language processing opportunities and risks, and governmental regulations of IT technologies

Digital Object Identifier 10.1109/MC.2022.3190786
Date of current version: 26 September 2022

 0018-9162/22©2022IEEE

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will be introduced and discussed. The column focuses on actual computing applications by using the appropriate technical depth together with an informative style.

COMPUTING BENEFITING HUMANITY

One of the areas where novel machine intelligence techniques and tools are extensively used with benefit for a large number of people is health. Many computing systems and software solutions are effectively used for detecting diseases, supporting doctors, helping patients, making discoveries in life sciences, improving health-care processes, and saving lives. This is an application sector where several success stories of computing benefiting humanity can be reported. Considering only the recent COVID-19 pandemic, vast scientific literature has been delivered by members of the computer science community that provided innovative solutions for fighting the virus. For example, researchers at the University of Central Florida and the U.S. National Institutes of Health have implemented a deep learning algorithm almost as accurate as a physician in diagnosing COVID-19 in the lungs and distinguishing COVID-19 cases from influenza.[1] Heterogeneous, multinational training data were obtained from hospitals across China, Italy, and Japan. The experiments show that the algorithm may be trained to classify COVID-19 pneumonia in computed tomography (CT) scans from oncology, emergency, and pneumonia-related indications with up to 91% accuracy, and to appropriately identify positive cases 84% of the time and negative cases 93% of the time, demonstrating generalizability to unseen patient populations and centers. This and other studies demonstrate the potential for machine learning-based diagnoses through the analysis of chest CTs, reporting as high as 95% correct detection of COVID-19 lung pathology. In this diagnosis task, previously, CT scans were not generally used. Recent studies like this one, based on deep learning approaches, may be exploited as objective tools to assist with the assessment of imaging findings of COVID-19 and may serve not only as research tools but as complementary test tools or for recurrent outbreak settings.

FROM THE EDITOR IN CHIEF

I'm a believer that, like coins, technologies have two sides. They can be used for good or ill. People often tend to focus on the ill side; so much is written about malicious and misuse cases. (Think about the many papers that you have seen about social media damaging society's fabric.)

This new quarterly column, "Humanity and Computing," will be different. It's going to focus on the positive side of computing. For example, let's discuss the role that computing played in the U.S.'s Operation Warp Speed initiative, which quickly resulted in multiple COVID-19 vaccines. This is the type of story that I want this column to focus on.

Prof. Domenico Talia is the column editor, so feel free to send him your ideas. I hope that you will look forward to reading, and possibly writing for, this new offering.—*Jeffrey Voas*

Computing technologies also helped a lot with analyzing COVID-19 pathology and with vaccine production. Algorithms have also been used to predict vaccine hesitancy and optimize vaccine allocation and distribution. For example, a team of researchers in the United States have implemented a scalable algorithm to optimize vaccine distribution in an epidemic network that can potentially reduce the percentage of people infected up to seven times and up to 98% at the peak of the infection on a city-scale network. The researchers used a simulated social contact network for residents in Oregon and applied a machine learning algorithm they developed by comparing its advised vaccination strategy with a scenario in which doctors randomly vaccinated the same number of people. Graph analytics techniques have been used to identify an optimal set of vaccination nodes, "seeds," that minimize the effective number of network infections.[2] They leverage principles from a well-known problem in network science, that is, influence maximization, and used a parallel implementation of the algorithm using the Summit supercomputer at Oak Ridge National Laboratory, one of world's fastest such computers, to significantly reduce time to solution from a few hours to roughly 3 min on large networks. This work shows

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how combining machine learning techniques and a high-performance computing system—in this case, a hybrid CPU-GPU implementation—allowed for computing the largest number of possible solutions quickly and accurately so that critical problems like vaccine distribution optimization can be addressed in as close to real time as possible.

COVID-19 wasn't the only recent virus outbreak. The 2014–2016 Ebola epidemic in West Africa (mainly in Guinea, Liberia, and Sierra Leone) defined a serious health threat. By the end of the epidemic, 28,000 people had been infected, approximately 11,000 of them had died, for a case-fatality rate of 40%. To identify the disease dynamics and assess nonpharmaceutical control interventions, a team of U.S. and Italian researchers developed a computer-based model of Ebola transmission that integrated geographical and demographic data to overcome the limitations of previous nonspatial approaches.[3] They used a spatial, agent-based model with a Markov chain Monte Carlo approach to estimate virus-transmission parameters and evaluate the efficacy of interventions such as readiness of Ebola treatment units, safe burials procedures, and household protection kits. The computing model has found that the movement and mixing of Ebola and non-Ebola patients in hospitals at the early stage of the epidemic was a sufficient driver of the observed pattern of spatial spread. By August 2014, it was estimated that 38% of infections were acquired in hospitals, 30% in households, and 9% while participating in funerals. The model allowed healthcare personnel to evaluate intervention options. Thanks to the availability of an increasing number of Ebola beds in treatment units, hospital transmissions drastically decreased over time. In five months, they declined in hospitals from 38% to 17%.

Other than pandemics, we may cite many other fields in health care where computing technology is helping humans. Diagnostics, for example, is a sector where new algorithms and software systems are providing innovative solutions. Recently, an international research team has investigated the use of machine learning algorithms for Alzheimer's disease (AD) identification and prediction.[4]

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Indeed, there is presently a lot of interest in designing machine learning algorithms to find out syndromes like Alzheimer's that is the leading cause of dementia in older adults. Its incidence rates are increasing every year also because our aging population increases, and its effects will be deep on the social and economic sides. In the cited work, different classification algorithms such as decision tree, random forest, support vector machine, gradient boosting, and voting have been utilized. Classification results reached an average validation accuracy of roughly 85% on the test data. This accuracy score is significantly higher when compared to existing works and shows how AI techniques can be used for symptom diagnosis and prediction at the early stage of this kind of disease, which currently represents a major health concern. The analysis of data allowed researchers to also identify the stage at which a patient of AD is currently in. Detecting the stage helps doctors better understand how the disease is affecting patients so that the appropriate treatment may be put in place.

Concerning software models of health of elderly people, a team of researchers from the United States and Hong Kong implemented an AI-recommendation system based on self-organizing maps, which can estimate one's psychological age and future well-being.[5] The system exploits a deep learning model to provide a 2D map of human psychotypes and identifies the regions that are most vulnerable to depression. The map is then used to provide personalized recommendations for maximizing one's future well-being. The learning algorithm splits all respondents into clusters depending on their likelihood of developing depression and determines the shortest path toward a cluster of mental stability for any individual. This model of human psychology can be used in self-help digital applications and during therapist sessions. To demonstrate the system's potential, the team has released a free web application (www.futurself.ai) that lets people take the psychological test they developed.

In the United States, more than 500,000 cases of cardiac arrest occur every year, and approximately 61% of those incidents happen outside of a hospital, while 39% occur within one. The percentage of people who survive out-of-hospital cardiac arrest with care by medical services is, regrettably, only roughly 8%. Machine learning techniques are effectively also used for predicting cardiac arrest. Nakashima et al.[6] designed and tested an algorithm based on a gradient-boosting technique to predict the risk of out-of-hospital cardiac arrest by combining timing and meteorological data. Previous studies have shown an association between a low temperature and the incidence of cardiac arrest. The researchers developed and trained an algorithm on more than 500,000 of roughly 1.2 million cases of out-of-hospital cardiac arrests using either weather or timing data, or both. The results they obtained were compared with 135,000 such cases occurring in 2014–2015 to test the model's accuracy. By combining meteorological

and chronological variables in the predictive model, the predicted values fitted the observed values with high precision. Sunday, Monday, holiday, winter, low ambient temperature, and large interday or intraday temperature differences were strongly associated with cardiac arrest incidence. This kind of predictive model may be used for improving the prognosis of patients with an out-of-hospital cardiac arrest through a warning system for citizens and emergency medical services on high-risk days, which will contribute to minimize the effects of a cardiac arrest and save patients' lives.

Together with machine learning solutions, public health professionals have another key source to consult when looking for data, information, and techniques that help them protect people's health. Today, thousands of apps are available for handling many public health issues and users. Computer scientists and physicians have developed many smartphone applications that collect data to enhance therapy and help therapists make more timely interventions. Several of them are downloaded thousands of times and utilized many times a day by patients. For example, concerning heart problems, wearable devices such as a smartwatch are used to monitor and learn about an individual's vital signs. Using collected data, a smartwatch can alert a person to signs of an impending cardiac problem or a heart attack. For example, researchers at the Beth Israel Deaconess Medical Center have developed mindLAMP, an app that provides therapists with an overview of patient behavior and mental status. mindLAMP uses smartphone sensors to collect behavioral data like screen time, movement and sleep, and information from patients through surveys and cognitive tests. Doctors review the data to evaluate patients' mental health and tailor therapy routines with them. Boston University researchers created the Motivation and Skills Support app to deliver targeted social-goal assistance to patients based on location, movement, and audio data collected by their phones. Finally, researchers at the University of Washington are exploring the use of online search-history data to better understand suicide risk and improve medical processes to detect and prevent it. An algorithm they used in an attempted suicide retrospective study identified approximately 63% of attempts that had been made as early as six months before the event. As declared by John Torous, a psychiatrist and director of the Division of Digital Psychiatry at Beth Israel Deaconess Medical Center, these software systems are not used to replace or substitute for care, but to augment it, by partnering with patients to bring valuable new data into a therapy visit and offer increased support for patients between those visits.

Like other safety-critical application domains, health care is a very crucial field where computing technologies must be introduced with extreme caution. In Western countries, people of color sometime face disparities in access to health care and quality of care. Implicit attitudes and behaviors that exist outside of conscious awareness of health-care professionals have been identified as one of many factors that contribute to health disparities. In other cases, algorithm bias generates unfairness and discrimination. However, there are cases where algorithms may help in improving health diagnoses and treatments by correcting doctors' decisions. A recent study found that a deep learning algorithm used to analyze the experienced pain of patients suffering from osteoarthritis of the knee was able to better explain than therapists the level of pain people were feeling.[7] Researchers started to form the fact that underserved people experience higher levels of pain. This disparity persists even after human physicians used controlled medical images for the objective severity of diseases like osteoarthritis. Scholars have used a deep learning technique to measure the severity of osteoarthritis by using knee X-rays to predict patients' experienced pain. This algorithm significantly reduces unexplained racial disparities in pain by considering supplementary undiagnosed features that could be overlooked by doctors. Because patients who reported severe pain and scored highly on the algorithm's measurement but low on the official grading systems were more likely to be black, the system suggested that traditional diagnostics may be inadequate for serving that community. The study appears to be particularly interesting because, while AI methods have often been accused of being unfair, this case shows that there are cases in which an algorithm can do a better job than a human in improving the health of patients of a lower socioeconomic status.

The integration of AI into medicine and clinical practice has increased in recent years, and this trend is expected to continue to grow. As the trend will endure, the assistive role of computers can be played in solving real-world problems by enhancing physician's and "practitioner's" skills as opposed to replacing them. The intensive use of AI technologies, however, requires careful screenings, ethical behavior, legal frameworks, patient protection, and practitioner training. As the research studies mentioned in this article have shown, machine learning is working in health care to convey new solutions that support a vision of healthier living for everyone. For machine intelligence to achieve its goals of supporting healthier living together with impressive new solutions like the ones evidenced in this article, an accurate analysis of human values to be considered is a must. Deliberate and informed analysis will lead computer and life science researchers to improved opportunities for understanding diseases. New partnerships among clinicians, computer professionals, and patients will enable computing systems to better support people and communities to live healthier lives.

REFERENCES

1. S. A. Harmon *et al.*, "Artificial intelligence for the detection of COVID-19 pneumonia on chest CT using multinational datasets," *Nature Commun.*, vol. 11, no. 1, p. 4080, 2020, doi: 10.1038/s41467-020-17971-2.
2. M. Minutoli, P. Sambaturu, M. Halappanavar, A. Tumeo, A. Kalyananaraman, and A. Vullikanti, "PREEMPT: Scalable epidemic interventions using submodular optimization on multi-GPU systems," in *Proc. 2020 IEEE/ACM Int. Conf. High Perform. Comput., Netw., Storage, Anal.*, pp. 765–779, doi: 10.1109/SC41405.2020.00059.
3. S. Merler *et al.*, "Spatiotemporal spread of the 2014 outbreak of Ebola virus disease in Liberia and the effectiveness of non-pharmaceutical interventions: A computational modelling analysis," *Lancet Infectious Diseases*, vol. 15, no. 2, pp. 204–211, 2015, doi: 10.1016/S1473-3099(14)71074-6.
4. C. Kavitha, V. Mani, S. R. Srividhya, O. I. Khalaf, and C. A. T. Romero, "Early-stage alzheimer's disease prediction using machine learning models," *Frontiers Public Health*, vol. 10, no. 3, p. 853,294, 2022, doi: 10.3389/fpubh.2022.853294.
5. F. Galkin, K. Kochetov, M. Keller, A. Zhavoronkov, and N. Etcoff, "Optimizing future well-being with artificial intelligence: Self-organizing maps (SOMs) for the identification of islands of emotional stability," *Aging-US*, vol. 14, no. 12, pp. 4935–4958, 2022, doi: 10.18632/aging.204061.
6. T. Nakashima *et al.*, "Machine learning model for predicting out-of-hospital cardiac arrests using meteorological and chronological data," *Heart*, vol. 107, no. 13, pp. 1084–1091, 2021, doi: 10.1136/heartjnl-2020-318726.
7. E. Pierson, D. M. Cutler, J. Leskovec, S. Mullainathan, and Z. Obermeyer, "An algorithmic approach to reducing unexplained pain disparities in underserved populations," *Nature Med.*, vol. 27, no. 1, pp. 136–140, 2021, doi: 10.1038/s41591-020-01192-7.

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Digital Object Identifier 10.1109/MC.2022.3202581