Artificial Intelligence in Radiology

Luka Filipović-Grčić[1], Filip Đerke[2,3]

[1] Department of Diagnostic and Interventional Radiology, University Hospital Centre Zagreb, Zagreb, Croatia
[2] Health Centre Zagreb Centar, Zagreb, Croatia
[3] PhD student, School of Medicine, University of Zagreb, Zagreb, Croatia

Abstract:
Since its first use in medical purpose in the 1960s, the concept of artificial intelligence has been especially appealing to health care, particularly radiology. With the development of ever more powerful computers from the 1990s to the present, various forms of artificial intelligence have found their way into different medical specialties – most notably radiology, dermatology, ophthalmology, and pathology. Due to the growing presence of such systems, it is paramount for the specialists handling them to get acquainted with them in order to provide the best service for their patients. It is therefore the aim of this article to explain the most basic principles of artificial intelligence, accentuating the most prominent concepts used in radiology today, such as deep learning and neural networks. It will also mention some of the artificial intelligence systems approved for clinical use in the US, such as IDx-DR, used to discover more than mild diabetic retinopathy in patients over 22 years of age; and Arterys, used for cardiac segmentation and discovering liver and lung nodules. Same as in many other fields, there is a constant need for improvement – in construction, testing, and application of these new technologies. Many ethical questions are asked, considering privacy and liability of artificial intelligence systems in clinical use. One of the greatest concerns for radiologists is the possibility of being replaced by these systems. This scenario seems to be far-fetched, at least for the time being. Radiologists should use that time to get to know the "enemy". If they accomplish this, they might discover that they had had an ally all along.

Keywords: artificial intelligence, radiology, deep learning, neural networks, radiomics, clinical application of artificial intelligence

Sažetak:
Otkako je prvi put upotrijebljen u medicinske svrhe, koncept umjetne inteligencije pokazao se vrlo privlačnim za zdravstvenu skrb, posebno radiologiju. S razvojem sve moćnijih računala od devedesetih naovamo, različiti oblici umjetne inteligencije pronašli su put ka primjeni u raznim medicinskim specijalnostima, ponajviše u radiologiji, dermatologiji, oftalmologiji i patologiji. S obzirom na sve učestaliju prisutnost takvih sustava, važno je da se specijalisti koji se njima služe obrazuju o njihovim karakteristikama kako bi svojim pacijentima pružili najbolju skrb. Stoga je cilj ovog članka objasniti neke od osnovnih postulata umjetne inteligencije, s naglaskom na one najčešće korištene u radiologiji, poput dubokog učenja i neuralnih mreža. Također će se spomenuti neke od sustava koji koriste umjetnu inteligenciju, a dobili su odobrenje za kliničku uporabu u Ujedinjenim Američkim Državama. Takvi sustavi su Idx-DR koji otkriva više od blage dijabetičke retinopatije u pacijenata starijih od 22 godine, i Arterys, koji rabi za segmentiranje srca i otkrivanje nodusa u jetri i plućima. Kao i u drugim područjima, i ovdje postoji stalna potreba za poboljšanjima, kako u konstruiranju, tako i u testiranju i primjeni ovih novih tehnologija. Postavlja se mnogo etičkih pitanja vezanih za privatnost podataka i pravnu odgovornost sustava umjetne inteligencije u kliničkom okruženju. Jednu od najvećih briga za radiologe predstavlja mogućnost da budu zamijenjeni rečenim sustavima. Takav razvoj događaja ne čini se realnim, barem u doglednom vremenu. Radiolozi bi to vrijeme mogli iskoristiti da bolje upoznaju „neprijatelja". Ako uspiju u tome mogli bi otkriti da su u stvari cijelo vrijeme imali saveznika.

Ključne riječi: umjetna inteligencija, radiologija, duboko učenje, neuralne mreže, radiomika, kliička primjena umjetne inteligencije

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Correspondence:
Luka Filipovic-Grcic MD
luka.filipovicg@outlook.com
orcid.orcid.org/0000-0003-0024-8359

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The concept of artificial intelligence (AI) and its place in medicine has been a hot topic for the last few years. Indeed, there is a vast array of issues and concerns tied to the seemingly imminent and inevitable introduction of AI to almost all aspects of medical practice. The medical branch that first springs to mind when pondering AI is radiology. Already a highly digitized and computerized specialty, radiology may be one of the first specialties to profit, or, as some fear, to be overtaken by AI. Therefore, it is the aim of this article to introduce the readers to the basic concepts of AI, its current applications in medicine and radiology, to assess the potential pitfalls concerning AI, and to offer a future perspective.

Artificial intelligence is, in its most condensed definition, a branch of applied computer science where algorithms are developed and trained to perform tasks typically associated with human intelligence[1]. What this means in the world of medicine is that AI could mimic mainly the diagnostic abilities of physicians, thus improving the health service provided[2]. AI is in fact an umbrella term that encompasses many different features of computer science, each dedicated to solving a rather specific problem. These may include voice recognition, optical character recognition, but also complex social and emotional tasks. The main way in which a machine, or a human for that matter, can come to fulfill these tasks is through learning. The main concept that enables this is machine learning (ML). It can generally be understood as a process of improving the performance of an algorithm through experience, that is, without the explicit programing. The more the program does on its own, the more machine learning is involved[3]. ML itself can be divided into supervised and unsupervised learning, the supervised learning including labeled and annotated data and unsupervised without labels and annotations. Unsupervised learning relies on the ability of a given algorithm to cluster and organize data based on intuitive recognition of more or less subtle patterns. In radiology most current AI algorithms are trained using supervised learning[4]. Another form of machine learning is deep learning (DL), which constitutes of multiple layers (groups of functions), each assessing data for different features, each more complex than the other, in order to produce an end result. The most common algorithms in DL are neural networks, specifically convolutional neural networks (CNNs). As the name suggests, they are inspired by neural networks of the brain and emulate the brain function in a sense that they consist of multiple layers of neurons or knobs (functions really) each connected to all the neurons in the next layer. As some of the neurons in the first layer are activated, they cause some of the neurons in the next layer to activate as well, propagating the cascade through the entire network, producing an end decision or output, which is then compared to the label of a given data. The interconnections between neurons are functions which are initially randomly weighted so as to sharpen the pattern recognition through layers and come up with a single answer. That answer is then compared to the label of a given data in order to calculate the error or cost, that is the magnitude of the difference of the truth and a given answer. What follows is backpropagation, an operation of adjusting the aforementioned weights and biases in order to achieve the greatest decrease of the cost function tor a given example. In the process of learning the machine does this over and over again until it reaches a satisfactory level of accuracy. For a neural network or any deep learning program to work an extensive database is essential. This is a greatly simplified explanation of the mechanism behind CNNs and one could compare it to learning a song by heart; at first one says a lot of words wrong, but with each rehearsal the focus is set on the errors until one can sing the entire song flawlessly. The reason why neural networks are the most used AI algorithms in radiology is their ability to recognize patterns and classify images. As the network learns, it fits known patterns on new inputs and finds those that closely fit those patterns[6]. The layers of a network and entire networks can be combined with seemingly endless complexity for different tasks. As this field progresses, more and more innovative and interesting AI technologies are being tested; one such algorithm uses a swarm intelligence in order to augment the efforts of radiologists[7].

The current state of AI in radiology and medicine

Considering AI's applicability in fields with strong visual and image based components, four specialties emerge as candidates likely to be affected by the introduction of AI to health care: radiology, pathology, ophthalmology and dermatology. Contrary to what one might expect, one of the most progressive AI technologies to be approved by FDA for the use in the United States is IDx-DR, a software designed to detect more than mild diabetic retinopathy in patients older than 22 years. It is a screening system used in primary care that analyzes digital color photographs of a patient's retina. What is so special about this particular program is the fact that it is the first autonomous AI diagnostic system to be approved by FDA. However, although the system does not require immediate confirmation by a specialist, the whole point of it is to prompt the patient to seek specialist care[2, 9]. In 2017 FDA approved Arterys, a first deep learning clinical platform in radiology. It was approved for cardiac segmentation and subsequently in 2018 for assessing liver nodules on MR images and CT scans and lung nodules on CT scans. However, it still requires specialist supervision[2, 10]. With the advent of more sophisticated AI technologies able to detect information contained in radiologic images obscured to human viewers a new field emerged, radiomics. It represents the process of converting medical images, notably CT scans and MR images, into mineable high dimensional data, which, coupled with other patient characteristics lead to decision support model. This means that the system uses its integrational power to couple subtle radiographic features and other diagnostic results with evidence based medical knowledge to suggest future treatment and diagnostic possibilities. Another subfield of radiomics is radiogenomics, a field that seeks to correlate radiographic features of tumors with genomic patterns. Both radiomics and radiogenomics are expected to find their place in diagnostics and treatment of cancer patients [4, 11, 12]. At this point one should remember that the relationship of radiology and AI is old enough to have its own history. As early as 1967 there were attempts to harness the power of the computers in order to aid the efforts of radiologists in discovering lesions on mammograms. The concept came to be known as computer aided diagnosis (CAD) and it saw growing application in the last years of the 20th century as computers with adequate computational power were constructed. CAD is a type of software that relies on machine learning (supervised learning) to scan radiographic images for lesions, mainly tumors, and to mark them for a review by a radiologist. The usual way a digitized image is processed by CAD involves preprocessing, segmentation, region of interest analysis, classification, and final highlighting for the review. The radiologist may accept these findings or discard them as false positive. Two basic subtypes of CAD exist, the detection oriented CADe and characterization oriented CADx, the latter used mainly to distinguish malignant from benign nodules. Since the first CAD system was approved by FDA in 1998 for radiographic mammography, a myriad of CAD systems for different purposes have been developed, including detection of lung nodules and interstitial lung diseases on radiographs, CT and PET-CT images, detection of intracranial aneurysms on MR images, detection of vertebral fractures on chest radiographs, etc. One of the main differences between CADs and modern AI concepts is that CADs were envisaged and serve complementary to radiologists, that is, they play a supporting, rather than autonomous role in diagnostics. The chief hindering factor for further CAD development was its training, namely supervised learning, which restrained the machine from finding new, subtle patterns, relying instead on the ones visible to the human eye, missing the same discreet features as their trainers. Coupled with technologies such as deep learning, CADs may represent solid foundations for future development of AI image analysis[12-17]. Another important use of AI technologies in radiology would be workflow optimization. AI algorithms would recognize life threatening conditions in emergency service settings and prioritize these before others for a review by a radiologist thus reducing the time needed to establish a diagnosis and commence treatment[4]. Another time saving aspect of AI could be found in its application in image reconstruction, improving both the speed and quality of the final images[6, 18]. Considering the current state of AI in radiology and medicine, a path forward into the bright and advanced future with AI becoming standard of care and replacing physicians in a number of procedures along the way seems like a broad highway. Nevertheless, such a belief has been around for over half a century of AI history and the above mentioned scenario is still far from reality.

Issues concerning AI in medicine

If one thing is certain about AI it is the fact that it is incredibly complex, both in terms of creating and implementing. One of the most important conditions for construction and development of deep learning algorithms is an extensive, yet well defined and regulated database. It is essential, particularly in radiology, to create vast databases of radiologic images for machine training. Steps to achieve this goal have already been undertaken through organization of shared databases such as Visual Concept Extraction Challenge in Radiology (VISCERAL) Project[2, 19]. In order to organize such a database each and every image of usually hundreds of thousands demands a great deal of dedicated work to be prepared for use in training. Images need to be assessed by an expert radiologist, the diagnosis needs to be clinically confirmed and the image needs to be anonymized and deidentified before inclusion in a database. The General Data Protection and Regulation (GDPR), which became effective in the EU since 2018 touches on AI applications in medicine at many points, including the demand for explicit patient's approval for the use of their data, the ability to track what goes on with the data they provided and the option to retrieve their data, thus excluding them from all databases at any time. Above that, there is also a right to an explanation of the algorithmic decisions[20]. These legal implications will surely slow down the rate of development of AI systems as the industry adapts to new terms and conditions, however, it will also provide greater and broader understanding of these new technologies by the general public. The question of large datasets may well be the easiest and closest to solution at this moment. Indeed, most of radiologic images today are managed by digital imaging and communications in medicine (DICOM) standards and the picture archiving and communication system (PACS), thus enabling a standardized image management platform worldwide. Furthermore, the creation and sustaining of databases has become integrated in many institutional policies and the need of sharing these databases and interinstitutional and international collaboration has become apparent[2]. Another issue that may prevent further integration and growth of AI technologies in medicine is the lack of interoperability between systems of different providers. Different features of different systems should be complementary to one another for their simple and efficient use in different clinical settings[4]. There is also a concern among radiologists considering the interpretability or explainability of AI findings. In short, most AI systems do not elaborate how they reached a conclusion. To fix that Gradient-weighted Class.

Activation Mapping was developed, this technique marks the regions on the images that were crucial in deep learning model's assessment[21]. Further issues arise when it comes to conducting and evaluating studies and results of AI model's tests. Often an early mistake is made by the use of too small databases. This usually occurs in studies dealing with rare diseases and conditions where compiling a big enough database represents a challenge.

Then, there is a question of adequate training of AI models. Sometimes models are trained and tested on the same datasets so the model's ability to assess new data is inadequate. Even when training and validation data are separated the separation may be flawed, leading to „information leakage“, resulting in worthless findings[12, 22, 23]. However, these and other methodological flaws are not incorrigible. At the end, it is a clinical trial with clearly defined patient outcomes that gets a final say concerning clinical verification and subsequent application of any given AI tool[24]. Of course, as with every other innovation concerning healthcare, important legal and ethical questions arise. It is still not clear who will be responsible for the findings that have consequences on patients' health, the provider of the AI algorithms, the physician who used them, or someone else. A great concern in the development of AI technologies is patient privacy. As stated earlier, deep learning algorithms require big databases to learn from, and these are not easy to accumulate. Therefore, there is a tendency to share these databases between multiple research centers and developers to allow them to make more advanced systems. As data are anonymized and deidentified it is vital that they remain so when shared. Another issue becomes apparent as the AI industry, as any other industry, revolves around profit. There are fears that the providers of AI systems may make them intentionally biased, in order to generate profit, e. g. by favoring specific drugs, etc. These are not easy questions, and surely, many more will arise as AI becomes more present in clinical settings. It is important to bear them in mind and create a meaningful discussion that will include all parties engaged in the development, application and final use of AI technologies[2, 4, 25, 26].

Conclusion

To conclude this rather general review of AI in radiology let us look to what radiologists may expect from AI. In the current state of affairs AI is still in most cases an augmentative tool, used to help, but not to replace radiologists. We should remind ourselves that it has been so for over half a century, without leading to a significant loss of jobs in this specialty. Over the past decades radiology has embraced a lot of technologies containing at least some aspects of AI. Although most of them could not match the human level of judgement they were not simply rendered useless, but the experience gained through their use was invested in creating new, more powerful systems. To put it simply, in our relationship with AI we are still the teachers. We are the ones who create and test them. The predictions are that in due course AI will exceed human performance, but, as it does so, humans may well be able to learn and enhance our own intelligence by learning from AI[6]. The final measure of success for both AI and humans remains the quality of patient care. For all the exciting achievements the present continues to offer, the future of AI in radiology remains vast and full of potential breakthroughs and dead ends. Perhaps it is best to let Sir Winston Churchill summarize where we are now with AI in radiology: Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.

Author contributions:

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Literature:

1. Goodfellow I, Bengio Y, Courville A. Deep Learning (The MIT Press, Cambridge, MA, USA, 2016)
2. He J, Baxter SL, Xu J, Xu J, Zhou X, Zhang K. The practical implementation of artificial intelligence technologies in medicine. Nat Med. 2019 Jan;25(1):30-36. doi: 10.1038/s41591-018-0307-0
3. Beam AL, Kohane IS. Big Data and Machine Learning in Health Care. JAMA. 2018 Apr 3;319(13):1317-1318. doi: 10.1001/jama.2017.18391.
4. Tang A, et al. CAR white paper on AI in radiology, Canadian Association of Radiologists Journal 69 (2018) 120e135
5. Chartrand G, Cheng PM, Vorontsov E, et al. Deep learning: a primer for radiologists. Radiographics 2017;37:2113e31
6. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18(8):500–510. doi:10.1038/s41568-018-0016-5
7. Rosenberg L, Lungren M, Halabi S, Willcox G, Baltaxe D, Lyons M. Artificial Swarm Intelligence employed to Amplify Diagnostic Accuracy in Radiology, 2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), DOI: 10.1109/IEMCON.2018.8614883
8. Esteva A, Kuprel B, Novoa RA, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature 2017;542(7639):115–118.
9. Price WN. Artificial Intelligence in the Medical System: Four Roles for Potential Transformation, Yale JL & Tech.(Forthcoming), 2019 - papers.ssrn.com
10. Bluemke DA. Radiology in 2018: are you working with AI or being replaced by AI?, Radiology, 2018 - pubs.rsna.org
11. Gillies RJ, Kinahan PE, Hricak H. Radiomics: Images Are More than Pictures, They Are Data. Radiology. 2016;278(2):563–577. doi:10.1148/radiol.2015151169
12. Aerts HJLW. Data Science in Radiology: A Path Forward, Clin Cancer Res; 24(3) February 1, 2018
13. Shin HC, Roth HR, Gao M, et al. Deep Convolutional Neural Networks for Computer-Aided Detection: CNN Architectures, Dataset Characteristics and Transfer Learning. IEEE Trans Med Imaging.

2016;35(5):1285–1298. doi:10.1109/TMI.2016.2528162
14. Doi K. Computer-aided diagnosis in medical imaging: historical review, current status and future potential. Comput Med Imaging Graph. 2007;31(4-5):198–211. doi:10.1016/j.compmedimag.2007.02.002
15. Suzuki K. Machine Learning in Computer-aided Diagnosis of the Thorax and Colon in CT: A Survey. IEICE Trans Inf Syst. 2013;E96-D(4):772–783.
16. Kohli A, Jha S. Why CAD Failed in Mammography. J Am Coll Radiol. 2018 Mar;15(3 Pt B):535-537. doi: 10.1016/j.jacr.2017.12.029.
17. Firmino M, Angelo G, Morais H, Dantas MR, Valentim R. Computer-aided detection (CADe) and diagnosis (CADx) system for lung cancer with likelihood of malignancy. Biomed Eng Online. 2016;15(1):2. Published 2016 Jan 6. doi:10.1186/s12938-015-0120-7
18. Zhu B, Liu JZ, Cauley SF, Rosen BR & Rosen MS. Image reconstruction by domain-transform manifold learning. Nature 555, 487–492 (2018).
19. Jimenez-Del-Toro O, et al. Cloud-based evaluation of anatomical structure segmentation and landmark detection algorithms: VISCERAL anatomy benchmarks. IEEE Trans. Med. Imaging 35, 2459–2475 (2016).
20. Goodman B & Flaxman S. European Union regulations on algorithmic decision-making and a 'right to explanation'. AI Mag. 38, 50 (2017).
21. Selvaraju RR, Cogswell M, Das A, Vedantam R, Parikh D, Batra D. Grad-CAM: Visual explanationsfrom deep networks via gradient-based localization. arXiv: 1610.02391 [Preprint]. 2016 Oct 7
22. Yasaka K, Abe O. Deep learning and artificial intelligence in radiology: Currentapplications and future directions. PLoS Med 15(11): e1002707. https://doi.org/10.1371/journal.pmed.1002707 (2018)
23. Zech JR, Badgeley MA, Liu M, Costa AB, Titano JJ, Oermann EK. Variable generalization performance of a deep learning model to detect pneumonia in chest radiographs: A cross-sectional study. PloS Med. 2018;15(11):e1002683. https://doi.org/10.1371/journal.pmed.1002683
24. Park SH, Han K. Methodologic Guide for Evaluating Clinical Performance and Effect of Artificial Intelligence Technology for Medical Diagnosis and Prediction. radiology.rsna.org. Radiology: Volume 286: Number 3—March 2018
25. Char DS, Shah NH & Magnus D. Implementing machine learning in health care—addressing ethical challenges. N. Engl. J. Med. 378, 981–983 (2018).
26. Jaremko JL, et al. Canadian Association of Radiologists White Paper on Ethical and Legal Issues Related to Artificial Intelligence in Radiology. Canadian Association of Radiologists Journal. Volume 70, Issue 2, May 2019, Pages 107-118