AI Makes Medicine More Efficient, Individual and Preventive

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1 Introduction

The history of medicine is marked by fundamental, sometimes disruptive innovations. Such milestones tend to go hand in hand with technological development, especially since the second half of the nineteenth century: The discovery of viruses and bacteria revolutionised the fight against infectious diseases, the introduction of anaesthesia alleviated the suffering and pain of patients, the use of X-rays marked the beginning of medical imaging, which opened up more and more applications in the course of digitalisation.

Today, medicine faces a new disruptive change: Artificial intelligence (AI) and machine learning (ML) have the potential to take prevention, diagnosis and therapy to a new level. With it, we cannot only store and retrieve individual and structural health data as needed, but also make them usable for automated and accelerated analysis and decision processes. AI and ML are fundamentally new because they can recognise patterns—similarities, deviations, parallels, repetitions, correlations, clusters, classes—in an unmanageable amount of digital information. They establish a separate discipline in computer science that goes far beyond the simple processing of complex measurement and survey data.

The spectrum of applications for pattern recognition in medicine and the entire health care system is broad. This article will focus on three key areas of

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application: 1) the detection of anomalies in medical image data, 2) the processing and use of sensor data and 3) the integration of health data for data mining.

2 Status Quo and Case Studies

2.1 Detecting Anomalies: AI and the Evaluation of Medical Image Data

X-ray, ultrasound (US), computed (CT) and magnetic resonance tomography (MRI)—imaging techniques have revolutionised medicine because they allow a view into the living organism. Estimates suggest that imaging provides about 90% of the total stock of medical data and is thus best suited for self-learning systems. Machine learning can support diagnostics particularly well when medical information is already available digitally. Especially in oncology or dermatology, AI-supported diagnosis programs are expected to provide valuable decision support because the characteristic image features of the different types of cancer are sometimes difficult to recognise and require intense training phase for the physician.

Initial demonstrations show how powerful AI is even today in the evaluation of images. The University of Heidelberg, for example, had more than 150 dermatologists compete against a computer algorithm in 2019, which had been trained provides a large number of annotated open-source images. The task was to classify suspicious lesions on 100 images and to distinguish between moles and black skin cancer. As a result, the algorithm outperformed 136 of the 157 dermatologists across all levels of experience in terms of average specificity and sensitivity (Brinker, et al., 2019). The largest study to date on automated skin cancer diagnosis, led by the Medical University of Vienna, also from 2019, reached similar results (Lancet, 2019).

The central question here is not necessarily whether the computer is better than the doctor. In many cases, a computer program is also superior to humans because it has constant performance 24/7. Monotonous and lengthy evaluations increase the risk of human errors, both in terms of false-positive results and possible micro-metastases being overlooked.

Intelligent algorithms can help here to drastically reduce the workload, for example by separating complicated from simple cases which can then be manually examined in a targeted manner. Especially in the screening of breast cancer, studies suggest that a combination of AI and experienced physician delivers the best diagnostic results (Scinexx, 2018). Similarly positive effects are promised by the interaction between physician and AI in the evaluation of very complex examinations, such as whole-body CTs.

Self-learning algorithms will more than revolutionise the classic imaging by X-ray, US, CT and MRI. The close collaboration between medicine and computer science will increasingly lead to completely new technologies. An example of this is the project “4D + nanoSCOPE”, in which FAU is involved as the lead partner. To better understand the bone structure and anatomy of humans and to detect, for example, damage caused by stress, X-ray microscopyis to be made possible for the first time on the living organism. The layer image calculation could also be used beyond medical research—for example, to examine microfractures or corrosion processes in natural and synthetic materials.

Another example of automated image analysis beyond CT and MRI is a method that is being researched at the Max Planck Center for Physics and Medicine in Erlangen. Here, blood is to be examined for certain diseases without having to send it to the laboratory. During analysis, the a blood sample flows through a narrow transparent channel, while the individual cells are captured by a high-speed camera. Up to 4000 images per second are searched by an intelligent algorithm for features that indicate diseases. Recently, the researchers have achieved a much-acclaimed discovery: A change in the red and white blood platelets can lead to “Long Covid”. A finding that could also pave the way for a possible therapy. The method is expected to find its way to clinical routine in the next two years and could become the AI-supported standard procedure even in general practice in the medium term (Fast & efficient diagnoses by artificial intelligence, 2021).

2.2 Using Sensor Data: From Lifestyle Wearable to Health Monitoring

In the monitoring of vital functions and motion data using embedded systems or microcomputers, medicine can benefit from an already established innovation from the lifestyle sector—so-called wearables. These are already successfully used to match information of certain biomarkers with those of our everyday behaviour and to draw conclusions about our health status. The latest apps turn electronic bracelets or watches into diagnostic devices for diabetes, arrhythmia or sleep apnoea. Wearables are based onhighly sensitive sensors that provide reliable information about breathing rhythm, heart rate or movement patterns, and require powerful algorithms that evaluate these data. Self-learning systems, which are fed with a sufficiently large amount of data, are later able to analyse deviating patterns and decide, for example, whether an increased pulse is the result of physical activity or should be interpreted as an alarm signal for a health disorder.

In clinical research, there are promising approaches to integrate sensors for monitoring lifestyles and movement patterns into practical everyday objects. For example, a pair of glasses was developed at FAU that look very similar to normal glasses but can capture up to 100 different biomarkers—from vital functions to food intake. The sensors in the temple measure, for example, muscle contractions and analyse chewing sounds. In this way, they provide reliable information about individual eating behaviour and even about the type of food. From such data, the system can derive behavioural recommendations, for example, for diabetics and also serve the doctor as a support for the therapy.

Another project on which neurologists and computer scientists are also researching in the Nuremberg metropolitan region is the monitoring of Parkinson's patients. The aim is to depict the everyday life of the patients as authentically as possible and to assess the disease progression more objectively. So far, the project has developed a sensor-equipped shoe that delivers over 700 measured values for gait analysis, including speed, stride length and evenness. Numerous clinical studies have confirmed that the parameters recorded correlate very well with the symptoms of the disease. Just as important as the construction of the shoe was the development of self-learning algorithms that can both understand the pattern of the individual gait and evaluate changes. In addition, a complex analysis of context factors is required to be able to assess, for example, whether a slowed step indicates a deteriorated health condition or whether the patient is just walking with his elderly mother. The intended goal is to generate objective scores from the sensor data, on the basis of which the appropriate therapy will be decided in the future.

Initial research projects are already dealing with sensors that are not placed on, but in the body. Smart implants being designed to support the healing of bone fractures. They do not only collect data, but should be able to specifically stimulate bone growth (Medica, 2019).

2.3 Information Systems: Data Mining for New Medical Standards

AI can advance medicine wherever electronic data is available. The more data is digitally recorded, the more information is accessible to systematic evaluation and thus also to learning methods and algorithms. Hospital information systems and electronic patient records, for example, are a true treasure for medical research, for the organisation of individual treatments or for the further development of telemedical services.

According to estimates, currently only about 50% of all patient information in Germany is digitised. Increasing this percentage gradually is the prerequisite for organizing medical care more efficiently. This is the only way for medical facilities to know, for example, immediately what previous illnesses the patient has, whether X-rays exist or which medications have already been prescribed. This can avoid multiple examinations, sometimes even unnecessary operations.

However, with the help of AI applications, medical informatics can not only optimise organisational processes, but also offer targeted decision support for diagnosis, therapy and follow-up care. An example illustrates this: A patient comes to his family doctor with non-specific complaints. He uses an AI-supported program that not only has access to the patient's anamnesis data, but can also compare the symptoms with a database of millions of disease cases. At the same time, the program searches the available literature for possible clues to the complaints.

Such a scenario can only become reality if the actors of the health care system—family doctors, hospitals, care facilities—are networked with each other on the one hand and use a homogeneous or compatible data infrastructure on the other. We are still far from both today, but there are approaches to change that. Since 2018, the BMBF has been funding several data integration centres in Germany as part of the Medical Informatics Initiative, one of them at the Universitätsklinikum Erlangen. Their goal is to pool the data of regional studies and health service providers and make them accessible for structured analysis (https://www.medizininformatik-initiative.de/de/konsortien/datenintegrationszentren).

3 Challenges and Solutions: The Handling of Data must be Regulated

The application areas already described show the gigantic potential of AI-supported medical informatics. Of course, as with any new technology, there are also reservations and—not to be left unmentioned—specific risks.

The convincing successes of self-learning algorithms in the evaluation of medical image data have triggered more than just storms of enthusiasm. . Occasionally, the—certainly not entirely serious—demand was raised to stop investing in the training of radiologists. The assumption that AI could one day replace medical professionals is unfounded and just as absurd as the idea that the calculator could make mathematicians unemployed. AI is not a competition, but a valuable decision support system that can significantly accelerate and improve processes. The final decision must be made by the doctor, the traditional examination is not made obsolete by AI.

However, more serious is the danger that commercial diagnostic programs—in a similar way to wearables—are used by patients without medical supervision. Anyone who relies solely on their smartphone for skin cancer screening or determines their heart rhythm exclusively with their own smart watch is taking high risks.

At the same time, however, there must also be an awareness in doctors' offices and clinics not to rely blindly on advanced technologies, because even intelligent algorithms can produce errors. This also applies to medical research in the evaluation of causalities. Identifying spurious correlations between different variables of a data set is ultimately not the responsibility of the machine, but of the human.

The most serious challenge in establishing self-learning systems in medicine is certainly data protection. Self-learning algorithms depend on extensive information—if this is not available or access to it is denied, AI cannot exploit its potential. On the other hand, individuals must be reliably protected from becoming transparent patients against their will. The solution to this dilemma, according to many experts, lies in voluntary data donation. In order to create or increase the willingness for this, individuals must be informed about the benefit of their donation and the use of personal data must be made transparent. Also, the possibility to revoke consent at any time can contribute to more acceptance and trust.

4 Outlook on AI in the Medical and Pharmaceutical Work Environment in 2030

Whether glasses, shoes or other wearables, sensor-based mobile computing in combination with AI algorithms holds enormous potential for the medical sector. —they range from promoting a healthy lifestyle to early diagnosis and monitoring of chronic diseases to support in acute emergencies. The monitoring of health status and even medication could increasingly be shifted from doctors’ offices and hospitals to the home enviroment—with expected positive effects for cost reduction in the health care system and for the psychological well-being of patients. Overall, AI-supported analysis of sensor data can help to make medicine more personalised and to focus more on preventive measures.

In addition, data mining offers considerable potential. The ambitious and rewarding goal is to pool the growing data treasures in a national infrastructure. On this basis, gigantic amounts of medical information could be meaningfully evaluated and empirical knowledge systematically generated and made usable by means of AI algorithms. Data mining programs are able to recognise, learn and interpret certain patterns in organised data sets. The detection of health risks depending on various factors—genetic makeup, lifestyle, demographic variables up to regional environmental influences—can not only improve the treatment of acute cases, but also revolutionise medical research, for example on the origin of diseases. It is to be expected that data mining algorithms in combination with exploratory multivariate statistics will reveal new correlations and causal relationships that have remained hidden to science so far.

We can also relate this back to imaging; by using large image databases, deep learning systems can do more than just easily detect known anomalies such as tumours. They can also help to decipher symptoms that can develop into serious diseases in later stages. An example of this are structural changes of the optic nerve head in the human eye and their influence on a later glaucoma disease (Diener et al., 2021).

5 Summary

We can have high expectations of what AI can achieve in medicine; the leap from research labs to widespread application can succeed. In many areas of application, intensive research is being conducted—but no one can predict what will have become established in medical practice in the next ten years. The example of autonomous driving shows that ideas sometimes take decades to work safely in everyday life. And some ambitious goals, such as deciphering the song of whales, could prove to be permanently unattainable. Artificial intelligence will change many things in medicine, but not everything.

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