5 Leveraging Artificial Intelligence Technology for Effective Early Diagnosis: Heart Issues

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5.1 Introduction

Artificial intelligence (AI) is the science of making machines do things that would require intelligence if done by men. AI can also be defined as the ability to make computers or machines learn to solve problems that would otherwise require human effort. The first concept of AI was proposed in 1956, by John McCarthy who defined AI as a branch of computer science concerned with making computers behave like humans. The main aim of AI in technology is to make computer systems and machines imitate human behaviour when executing tasks. Advances in computing power have made it possible to analyse large amounts of data quickly with consistency and accuracy using AI. As such, AI has expanded to almost every facet of modern life, including healthcare.

Artificial intelligence has been incorporated into the field of cardiovascular medicine and is increasingly employed to revolutionize the diagnosis, treatment, risk prediction, and clinical care. Heart failure (HF) has a high prevalence, and the mortality rate following hospitalization is quite high. Early detection of HF is of vital importance in shaping the medical and surgical interventions specific to HF patients. This has been accomplished with the advent of the neural network (NN) model, the accuracy of which has proven to be 85% (Farah et al. 2021). AI is used in analysing raw image data from cardiac imaging techniques (such as echocardiography, computed tomography, and cardiac MRI amongst others) and electrocardiogram recordings through the incorporation of an algorithm. Machine learning algorithms such as decision trees, neural network, and logistic regression methods used to build a decision-making model to diagnose congestive HF, and the role of AI in the early detection of future mortality has played a vital role in optimizing cardiovascular disease outcomes.

5.2 Machine Learning

Machine learning (ML) is a subset of AI made up of special algorithms that can automatically improve themselves impressively over time through experience. The dynamic learning nature of a machine learning system has made it appropriate for various applications, and a new way, to solve problems in a constantly changing environment which allows a machine to automatically learn from past data without programming explicitly. The goal of ML is to allow machines to learn from data so that they can give accurate output. Mitchell (1997) defined machine learning as a computer program that learns from experience (E)

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E. O. Nwaichi (ed.), *Modernity in Health and Disease Diagnosis: The Account from STEM Women*, Sustainable Development Goals Series, https://doi.org/10.1007/978-3-031-34963-8_5

with respect to some class of tasks (T) and performance measure (P), if its performance at tasks in T, as measured by P, improves with experience E. This definition can be related to the growth of a child in terms of behaviour. As a child grows, there is an increase in its experience E in accomplishing task T, which results in a higher performance measure (P). Arthur Samuel in 1959, defined machine learning as defined machine learning as the subfield of computer science that gives computers the ability to learn without being explicitly programmed. In this definition, computers are not programmed with specific rules, but they learn from huge amounts of datasets fed into them in the domain of interest which allows them to learn the patterns therein and gain experience to solve problems in the same domain. The acquisition of experience starts from learning.

As shown in Fig. 5.1, machine learning technique is categorized into supervised, unsupervised, and reinforcement learning. Supervised learning is used to solve classification and regression problems using categorical and continuous data and is task-driven. Unsupervised learning is used to solve clustering problems by dividing individuals into groups with similar characteristics and is data-driven. While reinforcement learning is used for decision-making and it learns from mistakes.

5.2.1 Supervised Learning

Supervised learning is the search for algorithms that reason from externally supplied instances to produce general hypotheses, which then make predictions about future instances. One of the tasks most frequently carried out by intelligent systems is supervised learning (Osisanwo et al. 2017). It is called supervised learning because the process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process. In supervised learning, the algorithm "learns" from the training dataset by iteratively making predictions on the data and adjusting for the correct answer. To "learn" is the process through which an algorithm modifies itself to being able to produce a certain result with a given input. Supervised learning involves the training of the model on a labelled dataset. There are two types of supervised learning: classification and regression.

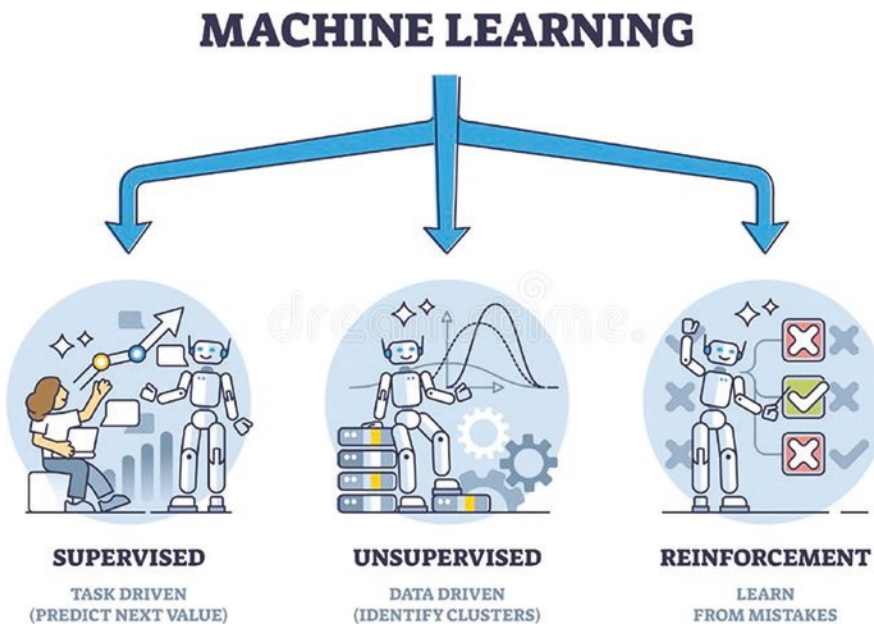


Fig. 5.1 Machine learning techniques (Source: https://www.dreamstime.com/about-stock-image-licenses)

5.2.2 Unsupervised Learning

Unsupervised learning involves the training of a model in an unlabelled dataset. The model learns on its own by learning the features of the training dataset. Based on those learning features, the model makes predictions on test data. Unsupervised learning aims to reveal hidden patterns in data. There are several types of unsupervised learning approaches and algorithms, and they include clustering, k-means to agglomerative, principal component analysis, and fuzzy C-means (Salim D, 2021).

5.2.3 Reinforcement Learning

Reinforcement learning is the type of learning guided by a specific objective. An agent learns by interacting with an unknown environment, typically in a try-and-error way. The agent receives feedback in terms of a reward (or punishment) from the environment; then, it uses this feedback to train itself and collect experience and knowledge about the environment (Muddasar et al. 2020).

5.3 Deep Learning

Deep learning is a subfield of machine learning inspired by the way biological neurons in the human brain work. Hence, the concept of artificial neural networks (ANNs) is the core foundation on which deep learning models are based. Figure 5.2 shows the performance comparison between deep learning and other learning algorithms. Deep learning performs better than traditional machine learning algorithm when trained with large amounts of data. However, model training time and model interpretability are still some of the factors slowing down the adoption of deep learning over the traditional machine learning algorithm in some of today's business environments.

Deep learning algorithms take longer time to train than traditional machine learning algorithms. The main reason for this is because there are many parameters used in deep learning and often, large datasets (in thousands and millions) are used for training the model and the training process involves many iterations in order to optimize performance. Another factor slowing down the adoption of deep learning is interoperability. Interoperability focuses on getting an explanation of how the model makes decisions. This is vital especially in a business environment because it aids trust in the model's decision by the various stakeholders. Deep learning has been applied to diverse fields such as speech recognition, social network filtering, bioinformatics, drug design, and medical image interpretation. Deep neural network is an example of a deep learning algorithm. It comprises of series of layers: an input layer, a cascade of processing units or hidden layers, and an output layer. Each of the layers comprises of individual neurons that extract and transfer data in a hierarchical fashion into more composite representations. Data from one layer is processed and fed into the next layer. Different types of neural networks have been developed; the type of neural network employed depends on the type and complexity of the analysis being performed (Kraus et al. 2020).

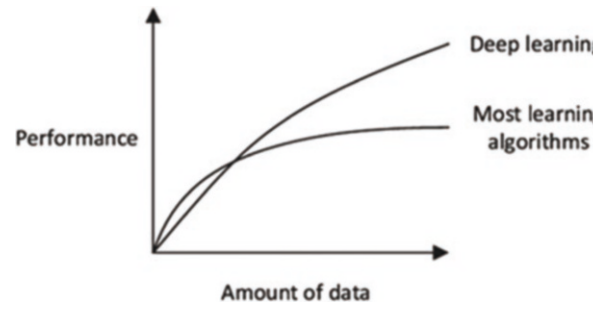


Fig. 5.2 Performance of deep learning vs. other machine learning algorithms based on the amount of data (Kraus et al. 2020)

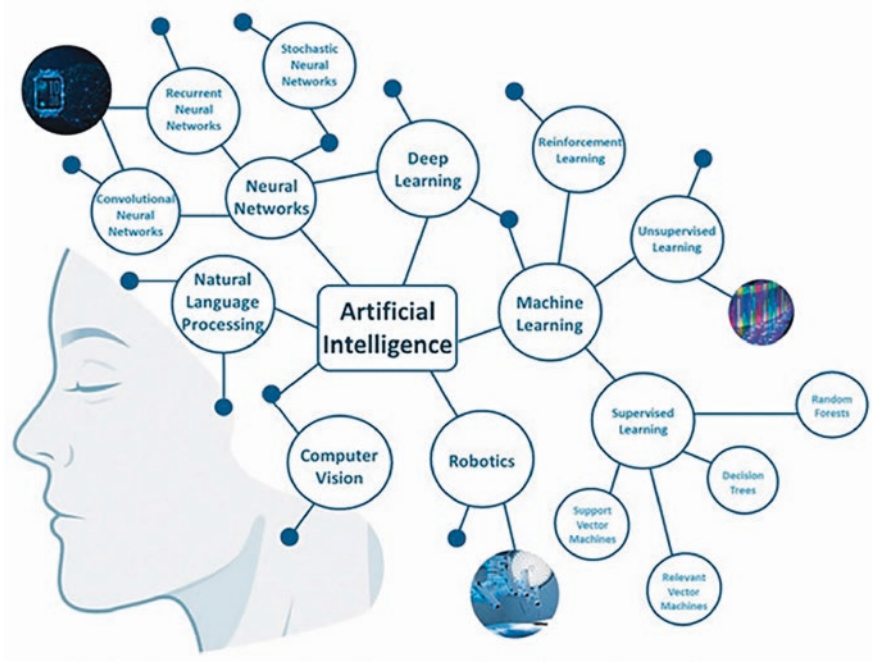


Fig. 5.3 Application fields of artificial intelligence (Konstantina et al. 2022). https://www.mdpi.com/2673-7426/2/4/49

5.4 Technical and Application Fields of Artificial Intelligence

Figure 5.3 shows some of the algorithms used in solving machine learning and deep learning problems such as the neural network, random forest, decision trees, support vector machines, recurrent neural networks, convolutional neural networks, and stochastic neural networks. The areas of AI technology are robotics, natural language processing, computer vision, and others. There are five schools of thought that AI development was based on, and they are Bayesian, connectionism, symbolism, evolutionism, and analogizers. Artificial intelligence can also be used for smart finance, smart education, smart healthcare, smart city, smart agriculture, smart home, and so on.

5.5 Overview of the Heart

The heart has been considered as the king of the body which supplies blood to different organs. The heart is made up of four chambers: the left and right atrium and the left and right ventricles. It is protected and anchored to the chest by a double-walled sac called the pericardium. The different chambers of the heart are connected by valves. Valves also connect your heart to the rest of the body. Blood is circulated by the heart through two pathways: the pulmonary circuit and the systemic circuit. The pulmonary circuit runs deoxygenated blood through the right ventricle to the lungs, where it becomes oxygenated before returning to the left atrium. In the systemic circuit, the oxygen-infused blood leaves through the left ventricle into the aorta. From there, it enters the arteries

and capillaries which supply one's tissue with oxygen. The deoxygenated blood then comes back to the heart and the process starts anew. As a muscle, the heart uses some of the oxygen as well, which means it has its own arteries. When these arteries experience blockage, a heart attack can happen. It can also cause damage and scarring to the heart. Improper performance can also cause a person to go into cardiac arrest.

5.6 Artificial Intelligence in Cardiology

Cardiology is a branch of medicine that specializes in diagnosing and treating diseases of the heart, blood vessels, and circulatory system. Heart disease refers to any condition affecting the heart. There are many types of heart diseases, some of which are preventable. AI can be used to program computers to process and respond to data quickly and consistently for better treatment outcomes, and this includes detecting heart diseases. AI can save time and improve reproducibility because the machines will do the work the same way, every time.

5.7 Application of Artificial Intelligence in Heart Attack Diagnosis

Kagiyama et al. (2019) developed a machine learning model to predict patients' long-term risk of a heart attack. This was done by combining coronary artery calcium scoring with non-contrast computed tomography, which indicates the accumulation of cholesterol within artery walls. Cardiologists can tell from the timing of the heartbeat in scans if there is a problem. This has saved a lot of patients from either being sent home and having a heart attack or undergoing an unnecessary operation.

Scientists at Google discovered a new way to assess a person's risk of heart disease using machine learning. This was done by analysing scans of the back of a patient's eye. The company's software can accurately deduce data, including an individual's age, blood pressure, and whether they smoke or not. This can then be used to predict their risk of suffering a major cardiac event such as a heart attack with roughly the same accuracy as current leading methods. The algorithm potentially makes it quicker and easier for doctors to analyse a patient's cardiovascular risk, as it does not require a blood test (Vincent 2018).

5.8 Application of Artificial Intelligence in Hypertrophic Cardiomyopathy and Cardiac Amyloidosis Diagnosis

Hypertrophic cardiomyopathy is a disease that causes the heart muscle to thicken and stiffen. As such it prevents the heart from relaxing and blocks blood flow out of the heart, resulting in damage to heart valves and fluid build-up in the lungs, making it harder for the heart to work and pump out blood, and causing abnormal heart rhythms. Figure 5.4 shows a normal heart tissue and the heart tissue with thickened ventricular septum, resulting in hypertrophic cardiomyopathy.

Cardiac amyloidosis is a disorder caused by deposits of an abnormal protein (amyloid) in the heart tissue as shown in Fig. 5.5. As amyloid builds up, it takes the place of the healthy heart muscle, making it difficult for the heart to work properly. Cardiac amyloidosis often goes undetected because patients might not have any symptoms, or they might experience symptoms only sporadically. The disease tends to affect older, black men or patients with cancer or diseases that cause inflammation.

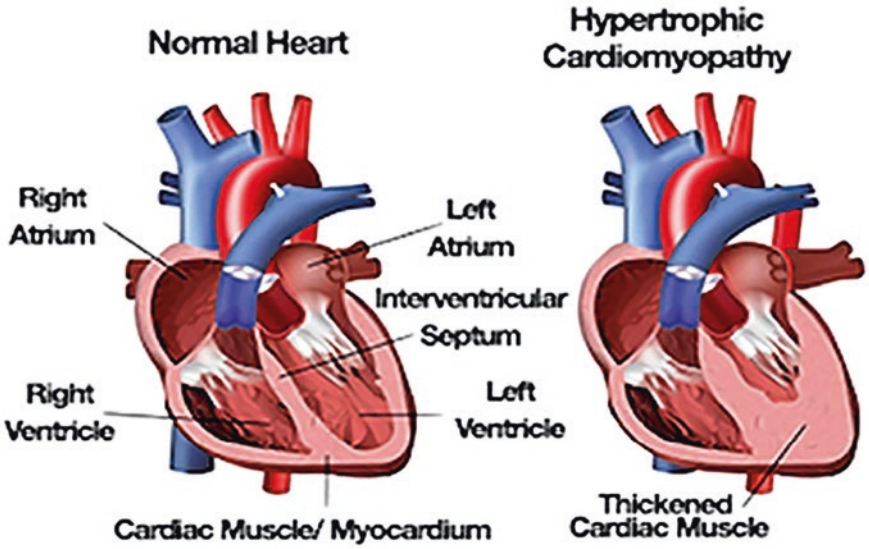
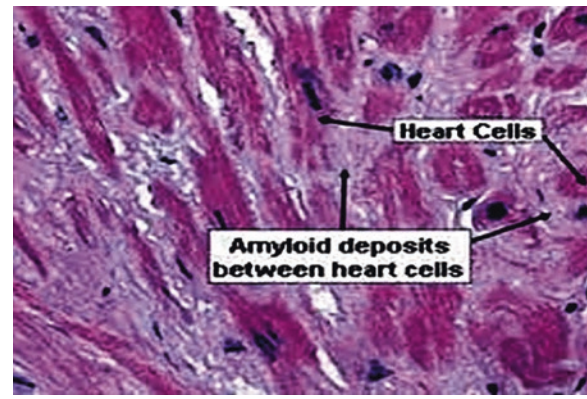


Fig. 5.4 Thickened ventricular septum (Source: https://utswmed.org/medblog/hypertrophic-cardiomyopathy/)

Fig. 5.5 Deposits of amyloid between heart cells (Source: https://www.google.com/imgres)



Duffy et al. (2022) developed a new AI algorithm that can effectively identify and distinguish between the two life-threatening heart conditions that are often difficult to diagnose: hypertrophic cardiomyopathy and cardiac amyloidosis. These two heart conditions are challenging for even expert cardiologists to accurately identify, and so patients often go on for years before receiving a correct diagnosis. According to Duffy et al. (2022), the AI algorithm they developed can pinpoint disease patterns that cannot be seen by the naked eye, and these patterns are used to predict the right diagnosis. The two-step, novel algorithm was trained on over 34,000 cardiac ultrasound videos from Cedars-Sinai and Stanford Healthcare's echocardiography laboratories. When applied to these clinical images, the algorithm identified specific features related to the thickness of heart walls and the size of heart chambers to efficiently flag certain patients as suspicious for having potentially unrecognized cardiac diseases. The AI algorithm identified high-risk patients with more accuracy than the well-trained eye of a clinical expert. This is because the algorithm picks up subtle cues on ultrasound videos that distinguish between heart conditions that can often look very similar to more benign conditions, as well as to each other, on initial review. Without comprehensive testing, cardiologists find it challenging to distinguish

between similar appearing diseases and changes in heart shape and size that can sometimes be thought of as a part of normal aging. One of the most important aspects of this AI technology is not only the ability to distinguish abnormal from normal conditions, but also to distinguish which underlying potentially life-threatening cardiac conditions may be present with warning signals that are now detectable, well before the disease clinically progresses to the point where it can impact health outcomes, because the treatment and management of each cardiac disease are very different, early diagnosis enables patients to begin effective treatments, prevent adverse clinical events, and improve their quality of life—a deliverable of SDG 3. Cardiac amyloidosis and hypertrophic cardiomyopathy often look very similar to each other on an echocardiogram, the most used cardiac imaging diagnostic (Duffy et al. 2022).

5.9 Conclusion

Artificial intelligence can help doctors in early diagnosis and treatment decisions. Estimating the socioeconomic impact of AI on health systems is fundamental to advancing the current discourse on the role AI can and should have in the health sector. With significant challenges lying ahead, such as an ageing population, growing demand for services, increased costs, and healthcare staff shortages, this industry should embrace AI. The speed of innovation in AI applications for the healthcare industry is increasing. A thriving ecosystem of start-ups, large medical technology players, and "Big Tech" companies are starting to roll out AI-enabled solutions. AI technology will help in early risk prediction and diagnosis of serious and complex heart problems, thereby saving lives.

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