# Artificial Intelligence and Radiology: Have Rumors of the Radiologist's Demise Been Greatly Exaggerated?

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Artificial intelligence is a rapidly evolving computerized technology affecting multiple aspects of our lives. It is predicted that artificial intelligence will lead to a fundamental change in practice of many professional fields, including medicine. One of the most significant advances in artificial intelligence involves digital imaging and image recognition. Consequently, radiologists, who work in the most digitalized field of medicine, need to be familiar with this rapidly progressing technology. "Artificial intelligence," "machine learning," and "deep learning" are terms that tend to be used interchangeably in terms of advanced computer algorithms, but each has a different meaning. Objectives for this article are to demystify these terms for radiologists and to establish a basic understanding of this topic for the reader. We also discuss the impact that artificial intelligence might have on the field of radiology in the foreseeable future. Although artificial intelligence is unlikely to replace radiologists any time soon (if ever), we explore how this technology could be beneficial to radiologists.

**Key Words:** Artificial intelligence; computer-aided detection; deep learning; machine learning; radiology.

## INTRODUCTION

Artificial intelligence is a rapidly growing technical field positioned at the intersection of statistics and computer science. Artificial intelligence is currently used in many industries and has multiple applications in health care. Recently, there has been increased interest in applying artificial intelligence to medical imaging for a more accurate diagnosis of diseases. Consequently, radiology could become the first medical specialty significantly affected by this rapidly developing field.

Artificial intelligence technology has existed for more than 50 years and has become increasingly sophisticated. The British mathematician Alan Turing, who was one of the founders of modern computer science and artificial intelligence, largely reserved the phrase "artificial intelligence" for a technology that could broadly mimic the intelligence of humans, which later became popularized as the "Turing test" (1). The present revolution in data science started in early 2013 with the advent of IBM's Watson supercomputer, which has immense computing power and the ability to analyze images with astonishing speed and accuracy. The advances in this field have been partially attributed to the wide availability of computer graphics processing units, which have made parallel processing faster, cheaper, and more powerful, allowing for major improvements in image recognition. In 2015, IBM purchased Merge Healthcare, providing supercomputers access to a vast amount of existing medical records data for the purpose of training to improve their ability to read imaging studies, initiating the entrance of large corporations into the realm of automated image interpretation (2).

The terms "artificial intelligence," "machine learning," and "deep learning" have different meanings but are often used interchangeably. The purpose of this article was to define and clarify these fundamental terms for radiologists and to discuss the effects that artificial intelligence could have on the radiology profession in the near future. We also discuss how this technology may soon be beneficial to radiologists.

## ARTIFICIAL INTELLIGENCE: BASIC TERMS AND PRINCIPLES

Before the advent of artificial intelligence, traditional computer programs relied on written lines of code to achieve a specific task. The computer did not "think" but simply performed the task as it was programmed to do. In recent years, advanced algorithms have allowed computers to make decisions autonomously. These computers are not explicitly instructed on the paths to use when performing specific tasks but rather rely on mathematical and statistical models to direct their decision-making to arrive at optimal solutions to problems. Artificial intelligence is the broadest way to consider this advanced computer intelligence. In 1956, at the Dartmouth Artificial Intelligence Conference, this technology was described as follows: "Every aspect of learning or any other feature of intelligence can, in principle, be so precisely described, that a machine can be made to simulate it" (3).

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Machine learning is one subfield of artificial intelligence. In 1959, Arthur Samuel, a pioneer in artificial intelligence research, defined machine learning as the "field of study that gives computers the ability to learn without being explicitly programmed" (4). By using statistical learning manipulations, computers can automatically discover patterns in input data. Unlike software programs that require specific instructions to complete a task, with machine learning, the computer system develops the ability to recognize patterns independently and make predictions. Machine learning is now being applied in multiple everyday applications, including data security, financial trading, marketing personalization, fraud detection, product recommendations, online searches, speech recognition, translation between languages, and smart cars.

In medicine, machine learning algorithms include computer-aided detection (CAD) applications that are used in mammography for the early diagnosis of breast cancer (5), in computed tomography (CT) for colon cancer diagnosis (6), in chest radiographs for the detection of pulmonary nodules (7), in magnetic resonance imaging (MRI) for brain tumor segmentation (8), in automated electrocardiographic (ECG) diagnosis of heart disease (9), and in functional brain MRI for diagnosis of neurologic disorders, such as Alzheimer disease (10). Machine learning can be classified into two major categories, that is, supervised and unsupervised.

In supervised machine learning, the user trains the program to generate an answer based on a known and labeled output dataset. The desired input and output data are fed into the computer by the programmer, and the computer learns the general rules and relationships between the inputs and outputs. The programmer "teaches" or "trains" the algorithm and directs it to the conclusions it should reach. The computer can then apply this "learned" knowledge to a new set of input data to generate the desired outputs unaided. Supervised learning takes advantage of our extensive prior knowledge of the different possible outputs. The computer is required to work through the process of assigning input datasets to predetermined output groups. Most currently available machine learning applications use supervised algorithms.

A common application of supervised machine learning is image recognition. For example, if the task is to sort a set of geometric shapes, the input data can be represented graphically as squares and circles. These inputs can be labeled manually, as shown in Figure 1. Because we know the outcome (output) in advance, that is, we know how to sort the images according to shape, we are able to "teach" the algorithm how to behave. We can then input an image of a square without the label and the algorithm will be able to sort the shape unaided, as shown in Figure 2.

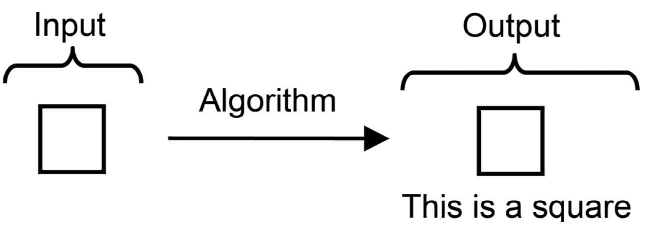


**Figure 2.** Supervised machine learning—execution. After training is completed, the algorithm is able to perform the sorting by itself on a dataset that it had been previously trained, using the same labeling that was used during training.

In unsupervised machine learning, the algorithm generates answers for unknown and unlabeled output data. Unsupervised machine learning is a more complex process than supervised machine learning and currently has fewer applications. No labeled outputs are provided in unsupervised machine learning. The algorithm determines how many different output groups there are and how to discriminate between them. The algorithm does this on the basis of mathematical and statistical models, without further guidance by the investigator. This method allows data mining and acquisition of new knowledge. Unsupervised machine learning can solve complex problems using only the input data and creates the potential to solve problems using methods that humans may not normally consider. Unsupervised machine learning is closer to the concept of true artificial intelligence in that the computer learns to identify complex processes and patterns without ongoing human guidance.

The previous example of digital geometric shapes can also be used to illustrate the unsupervised machine learning process, which is depicted in Figure 3. Again, the task is to sort geometric shapes. The algorithm sorts the shapes and assigns them into groups using its own labeling method. This output classification can also be applied to other shapes, as depicted in Figure 4.

The previous example highlights the fact that the output groups are not limited by predetermined specifications of squares and circles. The output groups can be the same as in supervised machine learning, different, or may even include additional groups that were not recognized or predicted by humans. The

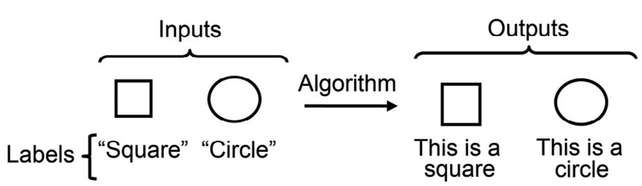


**Figure 1.** Supervised machine learning—training. Input geometric shapes are manually labeled by the operator and pass through the algorithm to "teach" the computer of the desired output sorting scheme.

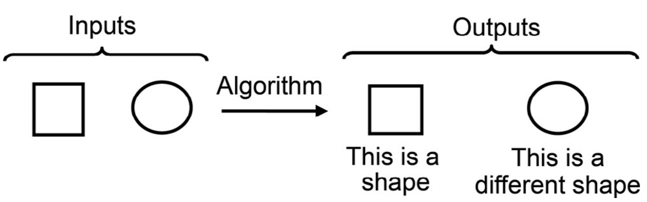


**Figure 3.** Unsupervised machine learning—training. The computer recognizes by itself the differences between the input data, with no manual labeling done by the operator. The computer sorts the input shapes into output groups using its own labeling method.

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