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Chapter

Introductory Chapter: Computer-Aided Diagnosis for Biomedical Applications

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1. Introduction

Cancer is a major public health problem with high morbidity and mortality worldwide [1]. Early detection and diagnosis are crucial for improving the 5-year survival rate [2]. Screening examination plays an essential role in the diagnosis of diseases [3], which produces a large number of images and requires physicians to interpret. However, human interpretation has many limitations, including short-term memory, inaccuracy, distraction, and fatigue. To solve these limitations, computer-aided diagnosis (CAD) has been applied in the biomedical imaging field.

The application of CAD in medicine can be traced back to the 1950s. In 1959, Lusted first introduced the mathematical model of CAD and put forward the model in medicine [4]. They successfully applied this mathematical model to the diagnosis of lung cancer, which became the pioneer of CAD. In 1963, Lodwick et al. applied a computer to analyze digitized chest radiographs [5]. In 1964, Becker et al. developed an automatic method to measure the cardiothoracic ratio in chest radiographs [6]. In 1966, Ledley first proposed the theoretical model of CAD [7]. In 1973, Toriwaki et al. [8] and Roellinger et al. [9] applied the CAD system in chest radiographs for the diagnosis of abnormalities and heart abnormality, respectively. In 1976, Winsberg et al. applied the CAD in mammography for diagnosis of abnormalities [10].

The CAD was further developed in the early 1980s, and the expert system applied in the field of medicine was the most noticeable one. The CAD processing includes medical information collection, quantitative and statistical analysis of medical information, and diagnosis. Popular models included Bayes theorem, maximum likelihood model, and sequential model. In the middle 1980s, researchers focused on the development and evaluation of CAD systems. Artificial neural network (ANN) has developed rapidly since the 1990s. ANN is a mathematical processing method that imitates the working principle of human brain neurons. ANN can play an assistant role in diagnosis due to it has the ability of self-learning, memory, and forecasting the development of events. Compared to the traditional methods (such as probability and statistics method, mathematical model), ANN offered better performance in classification and diagnosis. It can be said that ANN is one of the most advanced artificial intelligence technologies.

CAD studies reached a low ebb during the years after the 1960s until the early 1980s. This is because people hope to realize automatic diagnosis with the help of the computer, which is expected too much. The CAD studies are limited due to the lack of corresponding theoretical algorithms and theoretical analysis. This dual dilemma existed until the late 1980s and early 1990s. Thanks to the rapid development of computer, mathematics, and statistics technologies, CAD has been improved qualitatively. In recent years, the CAD system has been rapidly applied in medical imaging and has made gratifying achievements in some developed countries.

2. Basic principles of CAD

Computer-aided diagnosis or computer-aided detection refers to the combination of computer technology with medical image processing technology and other possible physiological and biochemical techniques to assist doctors for clinical decision-making and improve the accuracy of diagnosis. The computer-aided detection focus on the localization task, while the computer-aided diagnosis focuses on characterization task, such as the distinction between benign and malignant tumors, and classification among different tumor types. The computer only needs to annotate the abnormal signs and then carries out conventional image processing

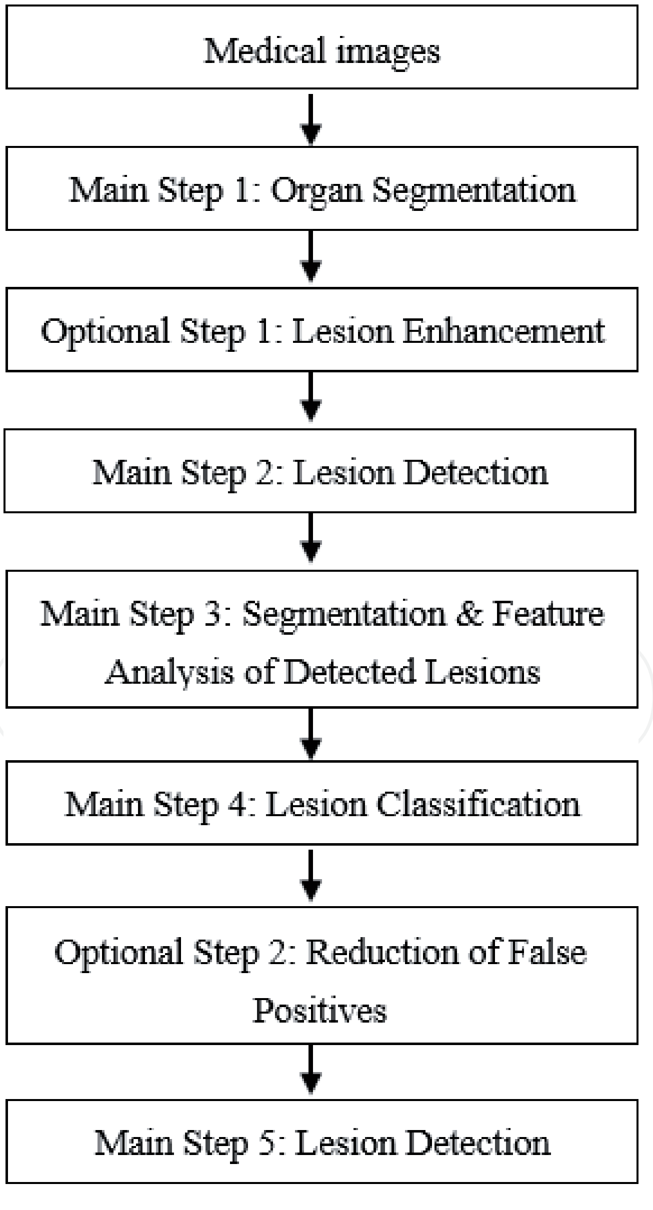

Figure 1.
Flowchart of computer-aided detection [11].

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without further diagnosis. In other words, computer-aided diagnosis is the extension and ultimate goal of computer-aided detection. Correspondingly, computer-aided detection is the basis and necessary stage of computer-aided diagnosis. Previous studies proved that CAD plays a significant role in improving the sensitivity, specificity, and accuracy of diagnosis.

Figure 1 shows the flowchart of the use of computer-aided detection in medical images for the diagnosis of lesions. The model consists of four main steps and two optional steps [11]. This first step makes the rest of the steps focus on the organ. The second step obtains a high sensitivity level because the sensitivity lost in this step cannot be recovered in the later steps. The third step aims to segmentation and feature analysis of the detected lesions. The fourth step aims to classify the segmented lesions by extracting pattern features such as gray-level-based features, texture features, and morphologic features. A machine-learning technique has been applied in this step. The machine-learning technique determines "optimal" boundaries for separating classes in the multidimensional feature space [12]. The final step classifies the detected lesions into the lesion and non-lesion groups. This step determines the final performance of the computer-aided detection scheme. The optional step 1 is applied to improve the performance of the system after the first step, which helps to improve the sensitivity and specificity of the detection in the subsequent step. The optional step 2 is usually applied at the end of the system to reduce false-positive rates, which could improve the specificity of the proposed CAD system.

Figure 2 shows the use of computer-aided diagnosis in medical images for diagnosis of lesions. The first step aims to detect lesions automatically or manually. The second step aims to segmentation and feature analysis of the detected lesions. The detected lesions are first segmented, and pattern features are extracted from the segmented lesions. With the extracted features, the lesions are classified into benign or malignant or different lesion types. This system may determine the likelihood of being malignancy or a specific type of lesion.

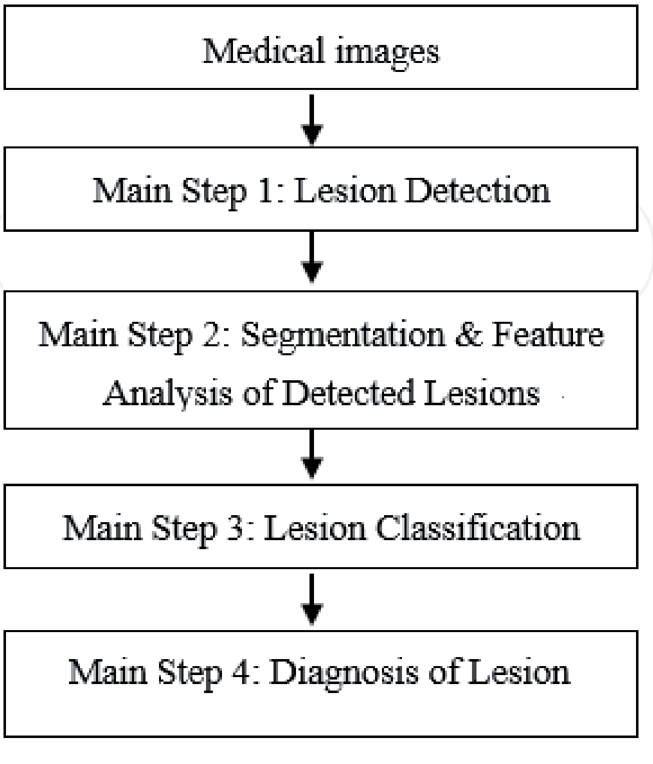

Figure 2.
Flowchart of computer-aided diagnosis [11].

3. Biomedical applications of CAD

Over the past few decades, several CAD systems have been approved by the US Food and Drug Administration to help in imaging situations [13]. Many investigators have studied CAD for diagnosis of various types of diseases, including lung diseases [14, 15], breast cancer [16, 17], stroke [18], liver cancer [19], microcalcifications [20], and artery disease [21].

At present, researchers worldwide have reached a consensus on the meaning of CAD in medical imaging. The final clinical decisions are still determined by doctors rather than machines, but doctors refer to computer output results before they make the final decisions. This makes the diagnosis more objective and accurate. They emphasize that the output of the computer is only a second opinion, which is different from the original concept of automatic computer diagnosis in the 1960s and 1970s.

The applications of CAD in medical imaging can help radiologists to improve diagnostic accuracy and consistency of image and disease interpretation. In other words, the computer outputs can be used as an auxiliary diagnosis but cannot be used as an ultimate diagnosis. The CAD system can help radiologists to improve the diagnostic accuracy because the diagnosis is entirely a subjective judgment process in traditional diagnostic methods, which will be limited and influenced by the experience and knowledge level of the radiologists. Radiologists may miss some minor changes in the diagnosis of disease. Besides, different radiologists may lead to different results due to image reading differences. The objective judgment of computer has excellent advantages in correcting these errors and shortcomings.

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Conflict of interest

The authors declare no conflict of interest.

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