International Journal of Advanced Culture Technology Vol.11 No.1 283-289 (2023)
DOI https://doi.org/10.17703/IJACT.2023.11.1.283

IJACT 23-3-32

Analysis of Trends of Medical Image Processing based on Deep Learning

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Abstract

AI is bringing about drastic changes not only in the aspect of technologies but also in society and culture. Medical AI based on deep learning have developed rapidly. Especially, the field of medical image analysis has been proven that AI can identify the characteristics of medical images more accurately and quickly than clinicians. Evaluating the latest results of the AI-based medical image processing is important for the implication for the development direction of medical AI. In this paper, we analyze and evaluate the latest trends in AI-based medical image analysis, which is showing great achievements in the field of medical AI in the healthcare industry. We analyze deep learning models for medical image analysis and AI-based medical image segmentation for quantitative analysis. Also, we evaluate the future development direction in terms of marketability as well as the size and characteristics of the medical AI market and the restrictions to market growth. For evaluating the latest trend in the deep learning-based medical image processing, we analyze the latest research results on the deep learning-based medical image processing and data of medical AI market. The analyzed trends provide the overall views and implication for the developing deep learning in the medical fields.

Keywords: *Medical Artificial Intelligence, Deep Learning, Marketability of Medical AI*

1. INTRODUCTION

Artificial Intelligence (AI) is bringing about drastic changes not only in the aspect of technologies but also in society and culture [1-3]. The medical field is one of the fields in which artificial intelligence technology is rapidly introduced, and big data analysis and deep learning technology are being actively applied to medical devices and medical services. AI technology based on big data analysis not only reduces the time and cost of medical services but also increases the accuracy of medical treatment and the life expectancy of patients.

IBM's Watson (Watson for Oncology) as artificial intelligence for medical services is a knowledge database-based service that uses a vast number of medical journals and professional books to help doctors' diagnose, but technical limitations and limited information of the Watson make it difficult to provide efficient medical services. On the other hand, Google's Deep Mind is an artificial intelligence based on deep learning algorithm using big data analysis for prediction. It has shown groundbreaking results such as predicting protein folding phenomena in addition to AlphaGo [4, 5].

Medical artificial intelligence algorithms using deep learning have developed rapidly. In particular, the

Manuscript received: January 31, 2023/ revised: March 1, 2023/ accepted: March 13, 2023
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field of medical image analysis has been proven that artificial intelligence can identify the characteristics of medical images more accurately and quickly than clinicians. For example, the international competition on AI cancer diagnosis technology at the Radboud University Hospital in the Netherlands in 2015 confirmed the effectiveness of AI-based cancer diagnosis by showing that the diagnosis results by AI are superior to those of cancer specialists.

Medical AI is playing a key role in the digitization of the healthcare industry. Medical AI is showing excellent results in the field such as medical big data analysis, clinical results, and patient diagnosis that is difficult to perform directly by humans. Medical AI has excellent strengths in rapid pattern analysis of massively sized datasets. In particular, it shows prominent results in the field of pattern analysis in radiology interpretation, ophthalmic treatment, cancer screening. It also shows better results than clinicians in the process of reading peculiarities such as lesions that are difficult to detect with the human eye. The developing trend of the medical industry according to advanced medical AI technologies is expected to be accelerated further [6, 7].

In this paper, we analyze the latest trends in AI-based medical image analysis, which is showing great achievements in the field of medical AI in the healthcare industry, and try to evaluate the future development direction in terms of marketability.

This paper is structured as follows. Section 2 analyzes AI-based medical image analysis technology to identify the characteristics of the latest technology. Section 3 analyzes AI-based medical image segmentation for quantitative analysis. In Section 4 we analyze the size and characteristics of the medical AI market and analyzes the limiting factors for market growth. Finally, Section 5 concludes.

2. AI-BASED MEDICAL IMAGE ANALYSIS

2.1 Medical Images

In order to identify diseases on various organs of the human body, medical images obtained by scanning human organs through various equipment are used. X-ray images are used as a simple way to identify lesions, and CT and MR images are used to scan tomograms of the human body. Figure 1 (a) and (b) show CT and MR images of the heart. Also, Figure 1 (c) and (d) show CT and MR images of the brain [7].

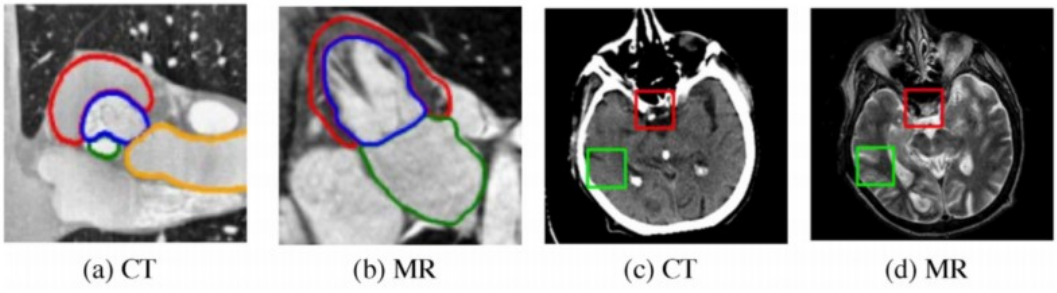

Figure 1. CT and MR Images for heart and brain

These images are analyzed by a resident to distinguish abnormal parts and identify lesions. Medical image analysis relying on human is subject to many limitations because the analysis by human takes long time and each specialist apply different standards on the same images. These limitations cause to need for AI-based medical image analysis.

Large-scale medical image datasets are essential for AI-based medical image analysis technology. In addition, not only the quantity of medical image datasets but also the reliability of images act as a very

important factor. LUNA16 (Lung Nodule Analysis 2016) is an open medical image data set provided for pulmonary nodule detection. LUNA16 contains 888 chest CT images and is a highly reliable data set in which pulmonary nodules were labeled by radiologists. Many research groups and companies are using the LUNA16 data set as basic data for detecting pulmonary nodules.

2.2 Deep Learning Technology for Medical Image Analysis

In order to automatically detect abnormal lesions through medical image analysis, it is very important to segment and classify internal structures of the human body in images. Segmentation of medical images was only possible manually by highly trained experts, so the segmentation work speed was slow and there were many limitations in the reproducibility of work results. AI-based medical image analysis technology enables to overcome those problems. AI-based medical image analysis means automatically detecting abnormal lesions by automatically segmenting and classifying internal structures of the human body in medical images using artificial intelligence technology. In this technology, automatic segmentation of human structures plays a key role. This technology is important in the aspect of detecting lesions because it can increase image reading efficiency by suggesting the experts the areas with high possibility of lesions in medical images by artificial intelligence.

To analyze medical images, we can adopt AI deep learning model as follows: Convolutional Neural Network (CNN), Fully Convolutional Network (FCN), Recurrent Neural Network (RNN), Mask Regional Convolutional Neural Network (Mask R-CNN), Generative Adversarial Network (GAN), Skip Connection Based Network.

CNN is a deep learning model representatively used in medical image analysis and is composed of multiple layers. The input layer of CNN receives medical images and transmits them to the convolutional layer that extracts the features of the images through filtering. The pooling layer reduces the output size from the convolutional layer, and the fully connected layer performs high-level abstraction on the results of the pooling layer. The output is determined through the output layer.

Figure 2 shows the CNN model analyzing chest X-ray images, that consists of input layer, convolutional layer, pooling layer, fully connected layer and output layer [7].

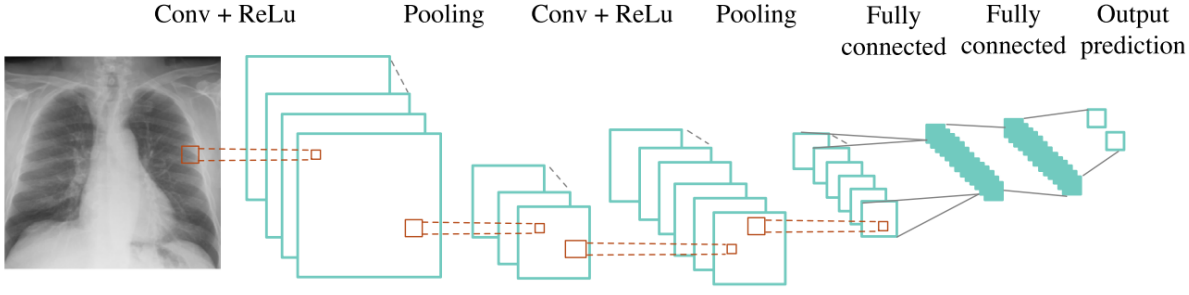

Figure 2. Convolutional Neural Network

The Mask R-CNN model and is a model performing object detection and segmentation in two steps. The model consists of a backbone network, feature pyramid network, region proposal network (RPN) and function branches.

In the first step, RPN of the model finds a box that encloses an object that has the possibility of the target object to be detected. In the next step, the target object is detected through the binary mask. Figure 3 shows object detection and segmentation using the Mask R-CNN model [7].

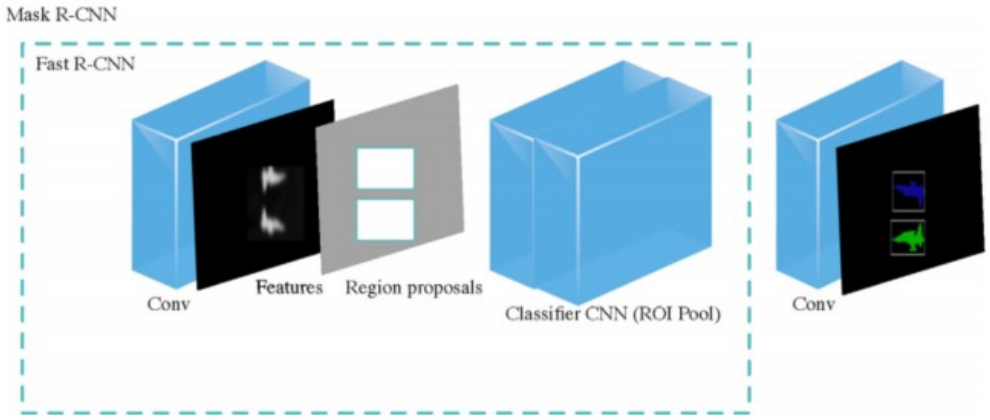

Figure 3. Mask R-CNN Model with two steps for object detection and segmentation

3. MEDICAL IMAGE SEGMENTATION

The automatic medical image segmentation technology enables consistent image analysis because medical images generated through various imaging equipment are converted into standard images by image reconstruction methods. In addition, quantitative analysis of medical images enables to apply the same criteria, so that the size of the lesion and the degree of progression of the lesion can be measured by consistent methods and be analyzed quantitatively. The image segmentation is a process of dividing the boundaries of human body structures in an image, and is a key task that enables accurate quantitative analysis for analyzing lesions.

Medical image segmentation mainly goes through the steps of generating learning data, creating a deep learning model, and training and evaluation. For example, Jihye Yun et al. 2022 shows the detailed process for lung bronchial segmentation in medical images as follows [8].

- Creating learning data for airway segmentation: for segmentation of the air way of lung, lung image data of the healthy as well as lung patients are gathered, and a learning data set is built through labeling.

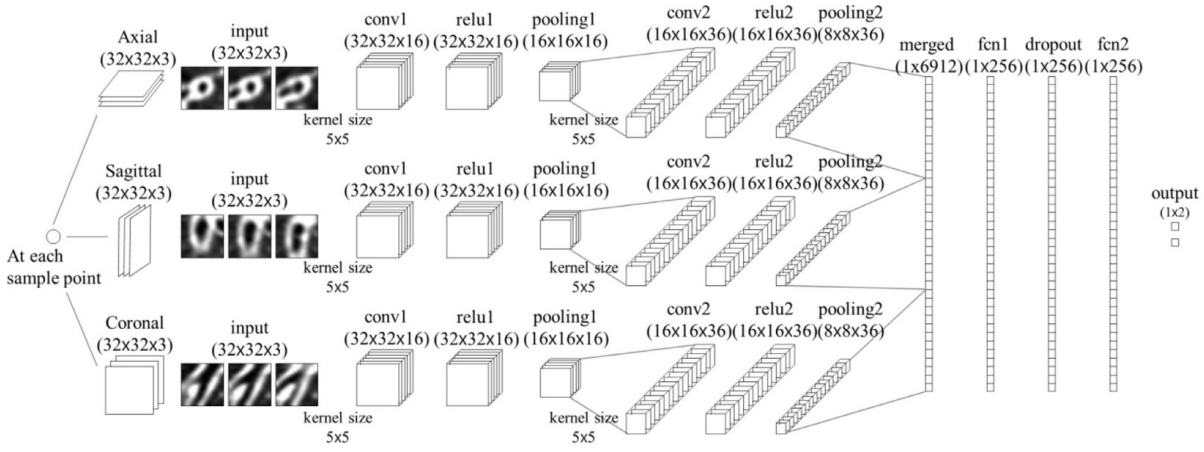

Figure 4. The 2.5D CNN model for segmentation of lung airways

Building a deep learning network: They built a 2.5D CNN model as shown in Figure 4 for segmentation of the airway [8]. They modeled the problem as a classification problem to determine whether the bronchus is present in the image or not. The model is trained to infer using a local-iterative method. The model results in reducing total inference time more than existing CNN models. Figure 5 shows the result of segmenting the lung airways in the lung CT image using the constructed model [8]. Figure 5 (a) and (b) show a thoracic CT scan and initial airway. Figure 5 (c) and (d) show the result of 2.5D CNN and the result from manual segmentation [8].

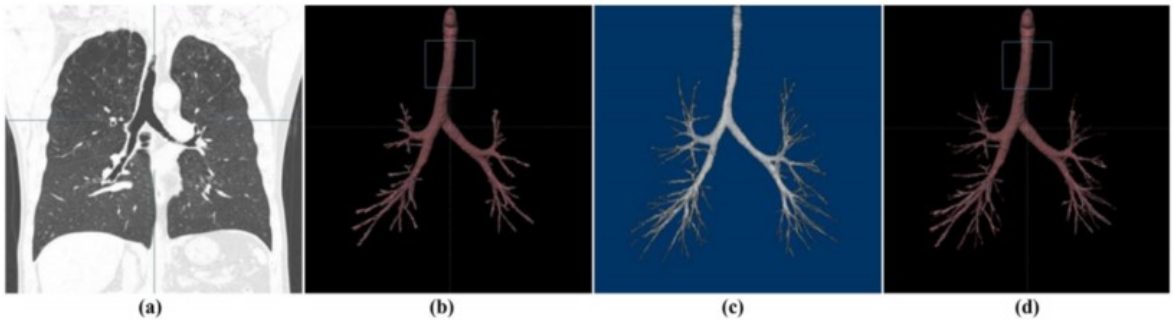

Figure 5. The segmentation of lung airways

4. MEDICAL AI MARKET AND RESTRICTION

4.1 Medical AI Market Analysis

Processing efficiently large amounts of medical data by the rapid developments of computer performance and deep learning algorithm lets the medical AI market be formed. The market size grows explosively with the expectation on reducing high medical costs and improving the accuracy of the medical services. In particular, as major pharmaceutical and biotechnology companies around the world introduce AI technology into the development of vaccines and medicines for COVID-19, the share of medical AI in the medical market is rapidly growing.

According to Artificial Intelligence in Healthcare Market Analysis by MarketsAndMarkets 2020, the global market size of AI-based medical field in AI technologies is expected to grow from $2.1 billion in 2020 to $21.8 billion in 2026 [9]. The global medical AI market is divided into software, hardware, and service segments, of which the software segment will grow from approximately US$ 1.3 billion in 2020 to approximately US$ 28.7 billion in 2026 and is expected to be the largest market share. Medical machine learning classification by use can be divided into medical imaging and diagnosis that deals with medical images such as CT, MRI, and X-ray, research use, and precision medical use. The analysis shows that the medical imaging and diagnosis market in the global medical AI field is expected to grow from US$ 530 million in 2020 to US$ 7.55 billion in 2026, showing a CAGR of 56.7%. The research use market is expected to reach $2.26 billion in 2026, increasing at a CAGR of 40.5% from $290 million in 2020. In addition, the precision medical use market is expected to grow from 160 million dollars in 2020 to 940 million dollars in 2026, showing an average annual growth rate of 48.4%. The market size of all the fields, medical imaging and diagnosis, research use, and the precision medical use, are predicted to increase with a high average annual growth rate.

Considering this analysis, the potential growth of the medical AI market is expected to be excellent, and a large amount of capital investment on the technologies is expected.

4.2 Restrictions on Medical AI

Since the medical device industry is related directly to life and health, governments of each country prepare institutional arrangements such as laws, regulations, licenses, certifications and standards to ensure reliability and safety of medical devices, and enforce to comply with them. These regulations have a great impact on the medical device industry, and government laws and regulations, as well as various licenses and permits, act as entry barriers for companies entering the business.

In the case of Korea, Medical Device Act Article 2 Paragraph 1 defines medical devices as instruments, machines, devices, materials, software, or similar products that are used alone or in combination with humans or animals. In addition, "Medical Device Act Article 3" designates the grades considering the purpose of use of medical devices and the potential harm to the human body during use. In 2017, the Ministry of Food and Drug Safety in Korea defined medical devices applying big data and AI for the first time in the world, and has applied the guidelines for classifications of them and licensing processes. The US FDA and European CE also prepare various regulations and certification systems for AI-based medical devices and provide guidelines for passing certification.

Regulations of AI-based medical devices is a measure to secure the safety of medical services. It, however, can also act as an obstacle to the applying developed technologies to medical services and also act as a potential barrier to market growth. Therefore, in order to improve AI-based medical services and grow the medical device market size, a balance is needed between technological development and legal regulations on the AI-based medical devices.

5. CONCLUSION

We have analyzed the technical characteristics of medical image analysis based on AI deep learning as well as the market size and market restriction factors in the medical AI market.

In AI-based medical image analysis, it is very important to obtain a large amount of highly reliable image dataset. Labeling performed by highly trained professionals is time consuming. Sophisticated labeling affects the performances of the AI models for analyzing medical images.

As a deep learning model, a variety of models can be applied such as CNN, FCN, RNN, Mask R-CNN, GAN, and Skip Connection Based Network. Especially, Mask R-CNN model plays an important role for medical image segmentation. Medical image segmentation is an essential element for quantitative analysis of medical images. It enables consistent medical image analysis using the same criteria. Accurate analysis has become possible with the development of AI-based medical image analysis, but highly trained expert judgment is essential. In the aspect of market, the medical image analysis market based on AI is expected to grow rapidly at an average annual growth rate of 56.7%, so the growth potential of the medical AI market is very excellent, and a large amount of capital investment is expected to be concentrated on the market. Legal regulation of AI-based medical devices is a measure to secure the safety of medical services, but it can also act as an obstacle to applying the AI technologies to medical services and also act as a potential barrier to market growth.

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