Research on computer aided diagnosis based on artificial intelligence

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Abstract. Magnetic Resonance Imaging (MRI) is a clinically important means of examination. Different pulse sequences can be used to obtain information about the structure, function, metabolism and other aspects of human tissues. Magnetic resonance imaging is also one of the most complex medical imaging methods. There are a lot of scientific and technical problems to be studied in various stages of magnetic resonance imaging, such as data acquisition, image reconstruction, image post-processing and image analysis. In this paper, the methods of data-driven and artificial intelligence are used to study the MRI image reconstruction, image processing and image analysis.

1. Background
Magnetic Resonance Imaging (MRI) is a commonly used diagnostic method, with the advantages of good tissue contrast and no ionizing radiation. In clinical practice, the patient is placed in the center of a magnet, and by controlling the gradient pulse and radio frequency pulse, the hydrogen atom in the patient's body (in general) is spatially encoded, the signal is collected to obtain the k-space data, and then the k-space data is obtained by two-dimensional Fourier transform to obtain the magnetic resonance image [1]. After a series of post-processing operations such as de-noising, segmentation, registration, marking and fitting, the multi-parameter magnetic resonance image is obtained for clinical diagnosis, which provides a basis for doctors' diagnosis. Can imaging of micro structure of the organization, using the statistical differences microstate reaction at the molecular level, such as Diffusion Weighted imaging (coursing together Weighted Image, DWI) can spread the information of water molecules within the organization, and according to the water molecules in the tumor cells and normal cells, which reflects the differences in tumor cells and normal cells[2]; Magnetic resonance imaging (fMRI) also can make Quantitative analysis, such as T1, T2 Quantitative imaging sensitivity Quantitative imaging, magnetic imaging (policy Susceptibility Mapping, QSM), etc., to be able to direct response organization of Quantitative information, for many degenerative diseases and neurological disease has important diagnostic value.

2. Introduction to machine learning, neural network and deep learning
Artificial intelligence technology can design computer programs to mine the data itself, extract features and information from the data, interpret the existing data and predict the unknown data through the
operation of data expression, regression and classification. At present, artificial intelligence has made amazing progress in the fields of computer vision, natural language processing, robotics, games and medical images [3]. At present, medical images are mainly read and interpreted by clinicians, and clinical reports are written based on the information of the images and their own experience, providing a basis for the design of the later treatment plan. Moreover, in the process of medical image reconstruction, artificial intelligence algorithm can perform image generation, denoising and reconstruction, and improve image quality.

Machine Learning (ML) is a branch of artificial intelligence, in which machines extract features from data and find patterns, and establish models to predict unknown data. Machine learning focuses on Prediction and Interpretation of the model. Prediction refers to whether the machine learning model can find out the rules in the data and make accurate judgment on the unknown data [4]. Interpretive means that the machine learning model can analyze the extracted features, find the rules in the existing data, and help people understand the model. Machine learning involves many algorithms. In general, highly explanatory models are not very predictive (such as decision trees and linear regression), while highly predictive models for complex problems are often difficult to interpret (such as neural networks and support vector machines with nonlinear kernel functions).

Neural Network is one of the many models of machine learning. It is a computational model that imitates the structure and function of biological Neural Network. The basis of the neural network is the perceptron. The basic structure of the perceptron is to calculate the weighted sum of the input characteristics with bias and apply the nonlinear activation function. The formula is as follows:

\[ f(x; \omega) = a(z) = a\left(\sum_i \omega_i x_i + b\right) = a(\omega^T x) \]  

(1)

Where \( x \) is the input features and bias, \( \omega \) is the eigenvector corresponding weight coefficient, \( z \) feature vector weighted sum, \( a(\hat{z}) \) means nonlinear activation function, commonly used nonlinear activation function with sigmoid and Linear rectifier Unit (LU) of Rectified Linear Unit, Re, etc.

![Fig 1. Schematic diagram of neural network](image-url)

Theoretically, a neural network with a hidden layer can approximate any function with arbitrary accuracy, but at the cost of increasing the number of nodes on the hidden layer by 30. Restricted by computing power, the shallow layer Neural Network hidden layer nodes is overmuch, can cause model low computational efficiency and high cost of model establishment, the Network design of recent years tend to reduce the each hidden layer nodes, increase the number of hidden layer upon layer, even if the
Neural Network structure changed deeply, now known as the depth of Neural Network (Deep Neural Network, DNN), online Learning is called Deep Learning, the artificial intelligence boom of recent years is caused by Deep Learning, including unmanned, image recognition, text analysis, etc.

Compared with traditional machine learning algorithms, deep learning does not require manual feature extraction of data, but can directly act on the data itself. Through multi-level feature extraction, deep neural network can extract features hierarchically. Through this multi-layer feature extraction method, deep learning avoids the defects of feature design and then learns the key features independently. In the field of medical image processing, the commonly used deep learning model is Convolutional Neural Network (CNN). The convolutional neural network extracts image features through convolution, increases the depth of the network to obtain more abstract features, and finally combines the higher-order features through the full connection layer to give the output result of the target problem.

3. Application of artificial intelligence in magnetic resonance imaging computer reconstruction

Medical image reconstruction is currently experiencing a third technology development, technology development is the use of imaging system for the first time the mathematical and physical model, through theoretical calculation and numerical simulation of the direct acquisition related digital signal, the signal analysis for medical images [5], such as magnetic resonance imaging (FMRI) was based on hydrogen atoms under the magnetic field of lamo precession and Fourier transform. The second technological development is to make use of the statistical laws behind the imaging system. These technologies tend to use iterative algorithms to reconstruct images with relevant constraints, such as sparse and low-rank. However, to transform the mathematical model to the practical application of images, it is still necessary to approximate the mathematical model. For example, sparse expression is constrained by L1 norm, and low rank is constrained by kernel norm.

Artificial Intelligence (AI) is one of the hottest areas of research in recent years. It usually refers to the technology of using computer programs to realize human Intelligence, and has made great achievements in such aspects as computer vision, natural language processing and unmanned driving. Artificial intelligence technology also has a wide range of applications in medical image, especially in image reconstruction, segmentation, simulation, quantitative analysis and other fields, artificial intelligence technology has an important use.

Magnetic resonance imaging (FMRI) k space data, after some Fourier acquisition, reconstruction using Convex set Projection (the Projection onto Convex Sets, POCS) algorithm is the use of k space data consistency and real images of k conjugate symmetry constraint iteration solving space; The compressed sensing algorithm performs iterative optimization by constraining the sparsity of the image domain and the data consistency of the k-space domain. Quantitative magnetic sensitive imaging can be used to reconstruct the image by restricting the sparsity of the image field and the consistency of the phase data. With the help of the continuity of image time series, the dynamic image of acceleration can be solved by the expression of low rank.

4. Application of artificial intelligence in post-processing and analysis of magnetic resonance image

With the rich sequence scans of the MRI equipment, we can perform different contrast magnetic resonance imaging for specific clinical problems, providing rich diagnostic information for the clinical problems. Clinicians usually interpret images according to their qualitative characteristics, so different doctors, or even the same doctor, give different diagnosis conclusions at different times. It is especially difficult to obtain a consistent diagnosis when there are additional factors such as poor image quality and irregular scan sequence. In addition, the physiological structure of human brain determines that clinicians' analysis of data is limited to qualitative features and macroscopic features, and they are unable to identify quantitative features and complex feature forms hidden under images.

According to Dr. Thurfjell, increasing the number of diagnostic physicians for the same MRI sequence can significantly improve the sensitivity of the diagnosis. In order not to increase the labor cost, computer-aided Diagnosis (CAD) can be used as the "second clinician" to make auxiliary decision on
diseases, so as to improve the accuracy of clinical Diagnosis. Much work has also demonstrated that computer-aided diagnosis can help clinicians make better diagnoses.

Generally, the steps of computer-aided diagnosis include image preprocessing, lesion segmentation, feature extraction and diagnosis conclusion.

Image preprocessing is to input digital medical image into computer software, and prepare for image denoising, registration, enhancement, etc. These operations are often customized for specific applications. For example, multi-parameter magnetic resonance images often need to be registered, images of different sequences are corrected, and image features with different contrast information are combined with image fusion, so as to find features related to the target problem.

Image segmentation: extract effective local areas from the entire Field of View (FOV) of the image for focused analysis. In this step, full manual sketching method can be used, and only software is needed to provide labeling tools. However, considering the high cost of manual labeling of multidimensional magnetic resonance data, semi-automatic labeling method and full-automatic labeling method are often used to assist clinicians in image labeling.

Feature extraction is an important transformation from qualitative to quantitative features of images. Usually, morphological features such as volume, length and diameter and gray scale features such as gray mean within the region and standard difference are extracted. Experienced clinicians can also distinguish them through long-term training. Feature extraction can also include more in-depth information mining, such as various texture features, or even quantitative analysis of images combined with a variety of transformations (TV, wavelet, etc.).

The diagnostic conclusion is to establish a mapping model from the feature to the diagnostic conclusion by analyzing the above extracted quantitative features and then correlating them with the diagnostic conclusion obtained by other methods such as pathological analysis. This process generally includes regularization processing of feature data, dimensionality reduction of data, feature selection, selection of appropriate machine Learning classification method, and training of the model through Supervised Learning. A trained model can not only analyze the characteristics of the existing data, but also diagnose the unknown data.

5. **k space under-mining mode**

In order to simulate the undermining of k spatial data, a random undermining method based on monte-carlo was designed. Based on the characteristics of high energy in the center of k space and low energy in the surrounding high-frequency part, the Probability Density Function (PDF) satisfying the gaussian distribution was generated. In combination with the partial Fourier technique and the central continuous acquisition strategy in parallel imaging, we give priority to the continuous acquisition of the low frequency part in the center of k space, and then the random undermining of the high frequency part. The acquisition sequence is determined according to the probability density function.

6. **Segmentation dictionary learning algorithm**

Based on the magnetic resonance image, the organization of internal signal difference is small, signal differences between the groups, we put forward for the magnetic resonance image Segmentation Dictionary Learning algorithm (Dictionary Learning with Segmentation, DLS), on magnetic resonance image of owe adopt zero fill a Dictionary before building, based on features of magnetic resonance imaging to organize the first Segmentation, Segmentation algorithm based on image gray scale, using the k means clustering algorithm analysis image gray histogram. According to the four main parts of the brain image, the image was clustered into four centers, and each point in the image was analyzed in a cluster, that is, the initial classification image was obtained. We constrain the signal strength within the same organization, calculate the grayscale mean of the same organization, and assign the mean value to all pixels in the same category to obtain the segmentation constraint image, and reconstruct the dictionary based on this image.
7. Traditional dictionary learning algorithm
The traditional dictionary learning algorithm can effectively extract the common information from the
data block according to the characteristics of the image itself, and form a dictionary, which is used to
quickly express the sparse image. The purpose of image reconstruction is achieved by sparse constraint.

The process of magnetic resonance image reconstruction using dictionary learning algorithm can be
represented by the following steps: first, image blocks are randomly extracted from the magnetic
resonance image containing artifacts to form a data set, and the initial dictionary is obtained; Update the
dictionary entries using k-svd (SVD) algorithm; New dictionaries are used to express blocks of images
using Orthogonal Matching Pursuit (OMP) algorithms. The image blocks were splicing into images, the
Fourier transform was applied to the fidelity of k-space data, and then the inverse Fourier transform was
used to obtain the final reconstructed image.

Compared to deep learning, video set is to learn the model training, low requirements for the amount
of data, clinical diagnosis problems generally dozens of cases of data can begin to try, on the one hand,
through the learning features of control, ensure the characteristic number matching with sample, on the
other hand image omics model training soon, you can use such as cross validation method, further reduce
the requirement for sample. Image group to learn because of using traditional machine learning
algorithms, don't like deep learning have higher request for calculating graphics, modern general
computer configuration to be able to run images of omics model, multithreading high-performance CPU
is in the process of training can speed up the training and the use efficiency, but common CPU can
satisfy certain requirements of operation. Image omics, accepted by clinical physicians, and now mainly
because of its good interpretability, extract characteristics have certain physical meaning, and easy to
understand and visualization, high interpretability of the model USES mostly classification model at the
same time, the operation model of explanatory, clinicians can through the model combined with his own
clinical experience, and this is the "black box" deep learning arithmetic.

However, according to the characteristics of MRI image, the traditional dictionary learning algorithm
cannot make use of the contrast features of MRI image. Based on this, the segmentation dictionary
learning algorithm is proposed in this chapter, which combines the characteristics of magnetic resonance
image with the traditional dictionary learning algorithm to optimize the reconstruction process and
reconstruct a better image than the traditional dictionary learning algorithm.

Taking the cross-sectional image of the brain as an example, the conventional structures such as t1-
weighted image, t2-weighted image and proton weighted image mainly include the structure of white
matter, gray matter and cerebrospinal fluid. On the premise of not considering such factors as bias field
and coil sensitivity, the signal strength within the same organization is similar, and the signal strength
between different organizations is greatly different. In other words, the distribution of the organization
within the image can be determined by histogram analysis of the image.

8. Conclusion
In feature extraction and modeling analysis, computer-aided diagnosis relies on the clinical experience
of clinicians and the image understanding of algorithm engineers. The characteristics of artificial design
are often good for the interpretation of known data, and poor for the prediction of unknown data or rare
diseases. The characteristics of design cannot reflect all the information of the target problem. The
design structure of the deep learning multi-layer neural network can carry out feature extraction based
on data adaptively according to the target problem, construct a model for diagnosis, and make up for the
defects of manual design features.

References
[1] Brown, R. W., Cheng, Y.-C. N., Haacke, E. M., Thompson, M. R. & Venkatesan, R. Magnetic
resonance imaging: physical principles and sequence design.
[2] Lemley, J., Bazrafkan, S. & Corcoran, P. Deep Learning for Consumer Devices and Services:
Pushing the limits for machine learning, artificial intelligence, and computer vision. IEEE
 Consum. Electron. Mag. 6, 48–56 (2017).
[3] Pons, E., Braun, L. M. M., Hunink, M. G. M. & Kors, J. A. Natural Language Processing in Radiology: A Systematic Review. Radiology 279, 329–343 (2016).

[4] Hirschberg, J. & Manning, C. D. Advances in natural language processing. Science 349, 261–6 (2015).

[5] Hanna, M. J. & Kimmel, S. C. Current US Federal Policy Framework for Self-Driving Vehicles: Opportunities and Challenges. Computer (Long. Beach. Calif). 50, 32–40 (2017).