Improving Histopathological Image Analysis through Artificial Intelligence and Deep Learning

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Abstract

Artificial intelligence (AI) has been leveraging its benefits since its evolution in every sphere of human life. It has benefitted the healthcare industry the most be it in detection of disease, prescription of treatment, etc. Using different techniques like image analysis, dimension analysis, etc. relevant features are extracted and with the evolution of supervised and unsupervised machine learning algorithms (MLAs) histopathology domain found its benefits in today's world. This paper review three different neural networks like ANN, CNN and VGG 16 and compare their respective accuracies in identification of liver disease intensity of liver in mice.

Keywords

Artificial intelligence, machine learning, supervised learning, image analysis

Introduction

Histopathology is a crucial aspect of clinical trials, providing a comprehensive understanding of disease mechanisms, and optimal tissue handling. Liver histopathology plays a crucial role in diagnosing bacterial diseases in animals. Various bacterial infections, such as leptospirosis, salmonellosis, and colibacillosis, can affect the liver, leading to histological changes like cellular swelling, fatty change, and necrosis ([1];[2]). In feline inflammatory liver disease (ILD) cases, the presence of intrahepatic bacteria was observed, suggesting a potential role in the disease's etiopathogenesis ([3]). Liver dysfunction due to bacterial infections can result from direct infection or inflammatory mediators, with abnormal liver function tests indicating liver involvement in septic conditions ([4]). Therefore, liver histopathology is essential for identifying bacterial infections and understanding their impact on animal liver health. Bacterial infections in mice can cause liver alterations, including necrosis, inflammation, hepatocyte degeneration, vacuolation, and inflammatory cell infiltration ([5]; [6]; [7]). These changes can manifest as hepatocytomegaly, bile duct hyperplasia, Kupffer cell activation, and cholangitis. Different bacterial infections lead to distinct molecular responses in the liver, affecting lipid metabolism, bile acid synthesis, and hepatic transporter functions ([8]; [9]). Understanding these histopathological alterations is crucial for developing targeted therapeutic strategies to mitigate the impact of bacterial infections on liver health in murine models.

The high demand for diagnostic tests can lead to work overload in pathology departments and delays in diagnosis, negatively impacting treatment assignment and effectiveness. An alternative approach is needed to reduce time and accurate prediction where the appropriate pathway is artificial intelligence.

Artificial Intelligence (AI) has significantly improved the analysis of medical images, particularly in histopathology diagnosis. Whole slide scanners have facilitated this process, enabling the generation of whole slide images (WSI) and enhancing pathologist workflow. AI-augmented histopathological diagnosis includes segmentation, quantification, and classification. The pipeline consists of training and testing phase, with the training phase focusing on image pre-processing, region detection, feature extraction, and model building. The testing phase compares extracted features to trained models to create a classification map. Pathologists interpret this map based on pathologists' criteria, but histopathology images have high visual variability and challenges like multi-class overlaps whereas, AI techniques for computer vision include hand-designed and trainable methods. Hand-designed methods segment images based on pixel similarities and differences, while deep learning methods, which have gained popularity for their superior performance, learn image features through training. Although estimating pixel probabilities in unseen images is challenging due to limited training data, deep learning shows promise in medical imaging, where detailed annotations are essential. Ongoing advancements in deep learning continue to enhance these methods ([10]).

Our study aim is to make the histology image accurate by different neural network and compare among them.

Material and method

Histology slide preparation

Mice liver tissues were dehydrated, preserved in xylene, and submerged in liquid paraffin for tissue embedding. Then, solid paraffin blocks were cut into small square pieces, sectioned, and transferred onto grease-free slides. Mayer's albumin was added to improve adhesion. Slides were heated to stretch and flatten the tissues, then permanently attached with a DPX mounting. In this instance, mice weighing 25 grams were employed as test subjects.

Image Capture

Histopathology slides were captured using a digital compound light microscope with a 16 MP SCOLUX camera. Top view software was used to capture images and transfer them to the laptop.

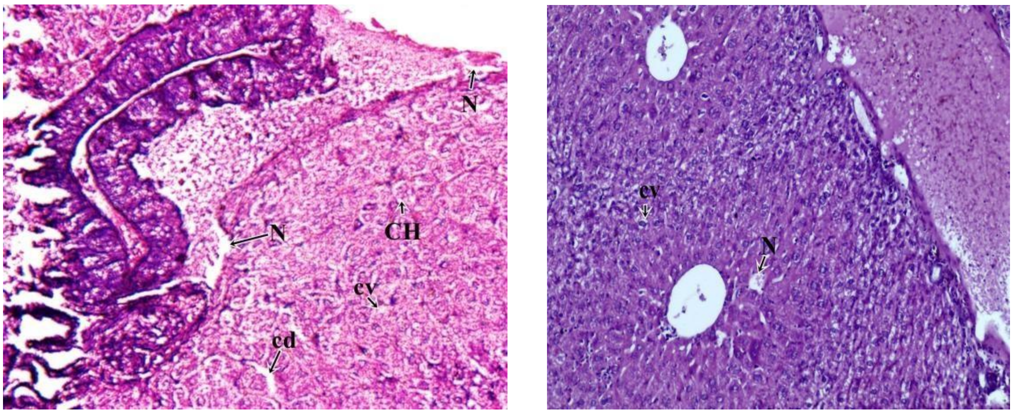

Fig.1 Histopathological image of liver

Data analysis

ANN is widely used neural network which is globally employed for detection purpose be it in health care or surveillance industry. Several features are extracted using three types of neural networks, namely ANN, CNN and VGG 16.

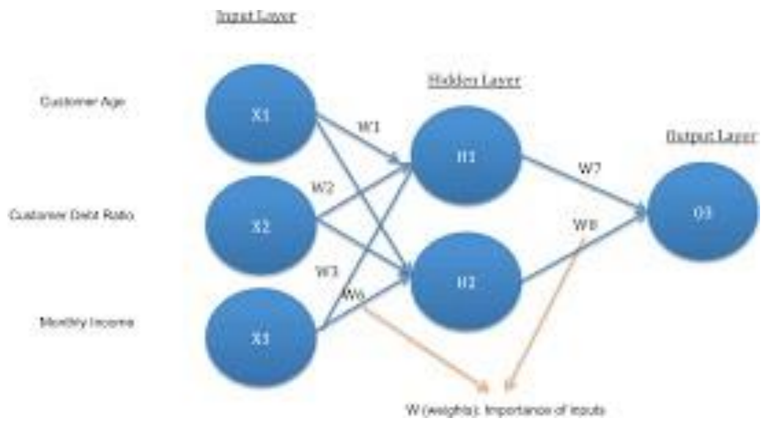

Fig. 2 ANN framework

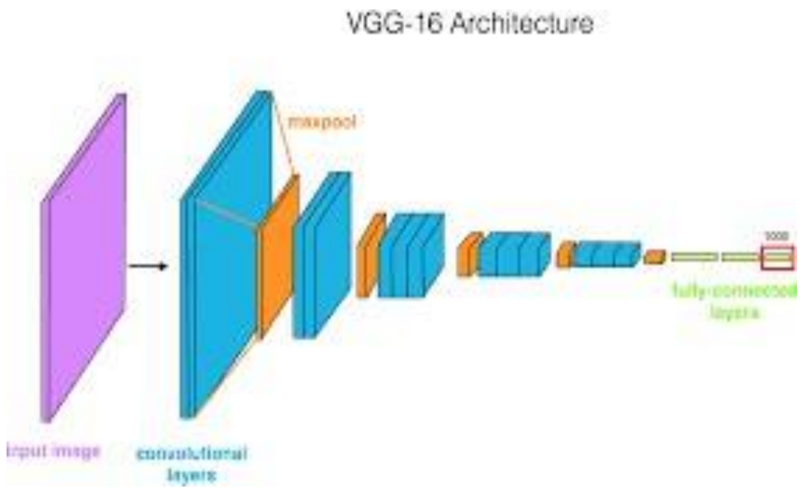

Fig. 3 Framework of VGG 16

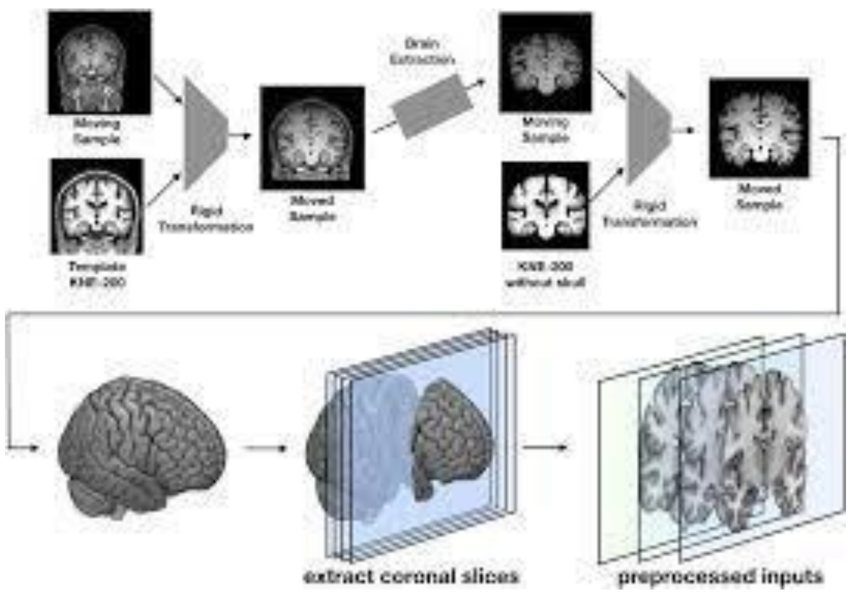

Fig. 4 Architecture of CNN

Table 1: Feature

	Liver	healthy	
CV	Cytoplasmic vacuolation	10	
CD	Cytoplasm degeneration	0	
CH	Cellular hypertrophy	0	
N	necrosis of liver tissue	35	
	Liver	infected	
CV	Cytoplasmic vacuolation	60	ATCC1
CD	Cytoplasm degeneration	60	
CH	Cellular hypertrophy	50	
N	necrosis of liver tissue	90	
	Liver	infected	ATCC2
CV	Cytoplasmic vacuolation	50	
CD	Cytoplasm degeneration	40	
CH	Cellular hypertrophy	50	
N	necrosis of liver tissue	65	

Result

A feature table is presented above. A comparative table is sketched to find the most accurate method of image detection technique.

Table 2: Disease detection comparison table

Sr. No.	Type	Network	Accuracy (%)	Acceptance Level
1	Supervised	ANN	95	Moderate
2	Unsupervised	VGG16	97.56	Highly moderate
3	Unsupervised	CNN	98.80	Highest

Discussion

The analysis of histopathological images using artificial intelligence presents a significant advancement in medical diagnostics, particularly in the context of liver disease detection. Our study demonstrated the effectiveness of three different neural network architectures in analyzing histological features of mouse liver tissue, with each approach showing distinct advantages and capabilities.

The histological examination revealed various pathological changes in infected liver tissues, including cytoplasmic vacuolation, cellular hypertrophy, cytoplasm degeneration, and tissue necrosis. These features were particularly pronounced in the ATCC1 infected group, which showed the highest levels of tissue necrosis (90%) and significant cytoplasmic vacuolation (60%), indicating severe liver damage. The ATCC2 infected group demonstrated moderately lower levels of damage, suggesting varying degrees of pathogenicity between bacterial strains.

Among the three AI approaches tested, CNN demonstrated superior performance with an accuracy of 98.80%, followed by VGG16 at 97.56% and ANN at 95%. The notably high accuracy of CNN can be attributed to its deep learning architecture, which is particularly well-suited for image analysis tasks. The hierarchical feature learning capability of CNN allows it to capture both low-level features like edges and textures, as well as high-level pathological patterns.

The implementation of VGG16, while slightly less accurate than CNN, showed impressive results with its deep architecture and standardized approach to feature extraction. The traditional ANN, while achieving a respectable 95% accuracy, demonstrated that even simpler neural network architectures could provide reliable results in histopathological analysis. CNN and VGG model used for tumor image analysis give 94% accuracy is already documented ([11]).

It was reported that, in histopathological image analysis, CNN get 95% accuracy and VGG model get 93% accuracy in non-alcoholic fatty liver disease (NAFLD) patient ([12]). The high accuracy rates achieved across all three methods suggest that AI-based analysis systems could significantly improve the efficiency and reliability of histopathological diagnoses. This is particularly relevant given the current challenges faced by pathology departments, including increasing workload and the need for rapid, accurate diagnoses.

Our findings align with previous research highlighting the potential of AI in medical image analysis, while also demonstrating specific advantages in histopathological applications. The success of these neural networks in identifying various pathological features suggests that AI could serve as a valuable tool for pathologists, potentially reducing diagnosis time and improving accuracy.

The study also highlights the importance of choosing appropriate AI architectures based on specific diagnostic needs. While CNN showed the highest accuracy, the other methods may be more suitable in situations where computational resources are limited or when specific types of feature analysis are required.

These results contribute to the growing body of evidence supporting the integration of AI technologies in medical diagnostics, while also providing specific insights into the relative effectiveness of different neural network architectures in histopathological analysis. Future research should focus on validating these findings across larger datasets and exploring the potential for implementing these systems in clinical settings.

Conclusion

In this study, we evaluated three neural network architectures (ANN, VGG16, and CNN) for their effectiveness in analyzing histopathological images of mouse liver tissue. Our comparative analysis revealed that CNN achieved the highest accuracy at 98.80%, followed by VGG16 at 97.56%, and ANN at 95%, demonstrating the superior performance of deep learning approaches in disease detection. The neural networks successfully identified various pathological features, including cytoplasmic vacuolation, cytoplasm degeneration, cellular hypertrophy, and tissue necrosis. The implementation of these AI-based systems shows promise in addressing the increasing demand for efficient diagnostic processes in pathology departments. The high accuracy rates achieved suggest that AI can serve as a reliable tool to assist pathologists in both clinical and research settings. These findings contribute to the growing evidence supporting the integration of AI technologies in medical image analysis, particularly in histopathological applications.

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