Accelerating Microstructure Recognition of Nickel-based Superalloy Data by UNet++

Kang Jia[1], Weifu Li[1,2,*], Zhelun Wang[1], Zijun Qin[3]

1 College of Science, Huazhong Agricultural Unversity, Wuhan 430070, China
2 Hubei Key Laboratory of Applied Mathematics (Hubei University), Wuhan 430062, China
3 The State Key Laboratory of Powder Metallurgy, Central South University, Changsha, 410083, China

Background

- **Nickel-based superalloy materials** have been widely used in many fields, and high-throughput preparation has been realized.
- However, the traditional methods to study its microstructure are no longer applicable.
- Here we use deep learning methods: **U-Net, UNet++** to improve the accuracy and speed of materials segmentation.

Methods & Results

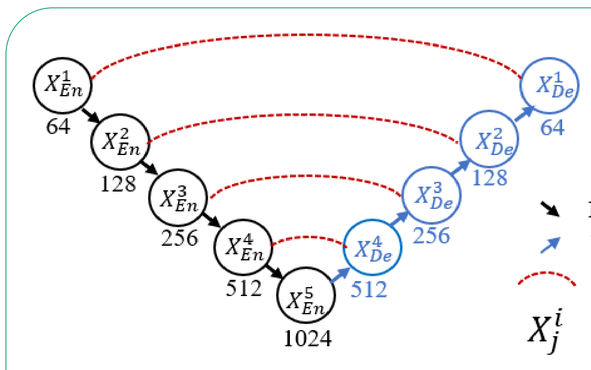

Figure 1 U-Net architecture, the black and blue arrows indicate the down-sampling and up-sampling, respectively. The red dotted curve denotes the skip connection. The X_j^i indicates the convolutional and pooling operations.

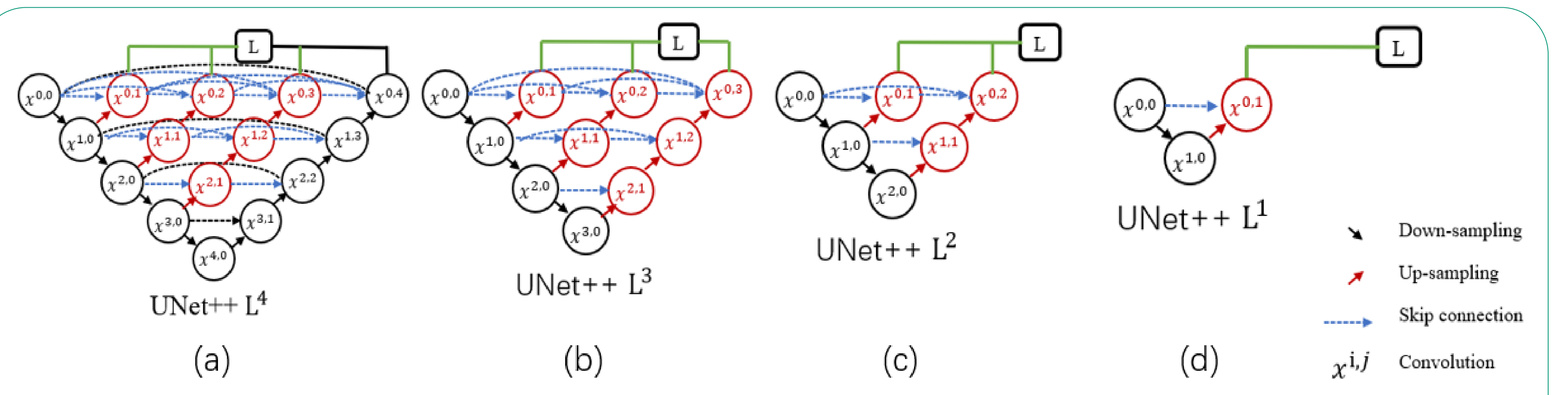

Figure 2 UNet++ :Different levels of pruning: (a) UNet++ L^4, (b) UNet++ L^3, (c) UNet++ L^2, (d) UNet++ L^1. The black and red arrows indicate the down-sampling and up-sampling, respectively. The blue dotted line denotes the skip connection. The $x^{i,j}$ indicates the convolutional and pooling operations. The green indicates deep supervision.

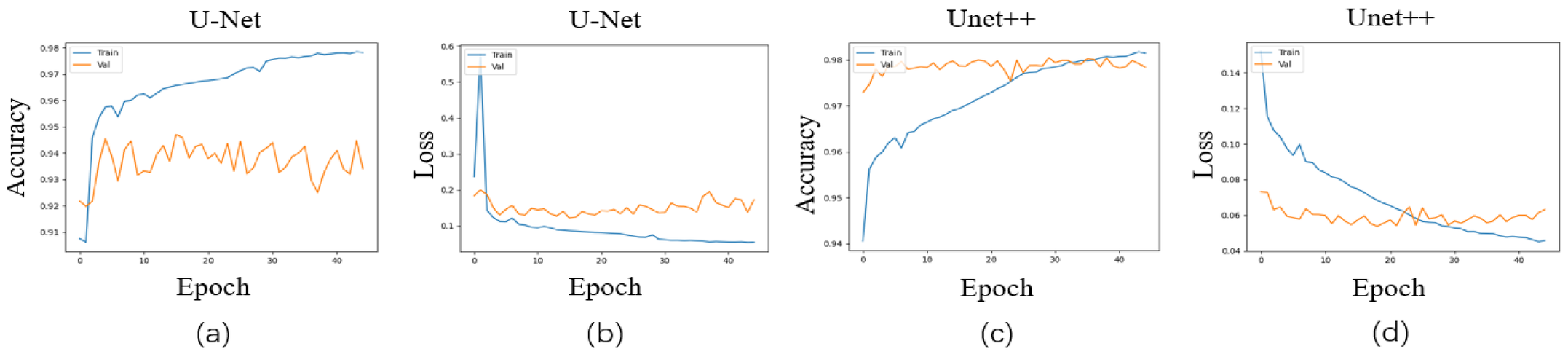

Figure 3 Accuracy and loss vs epoch: (a) U-Net model accuracy, (b) U-Net model loss, (c) UNet++ model accuracy, (d): UNet++ model loss. U-Net++ almost has the same performance between the train set and validation set while the U-Net is a little over fitting.

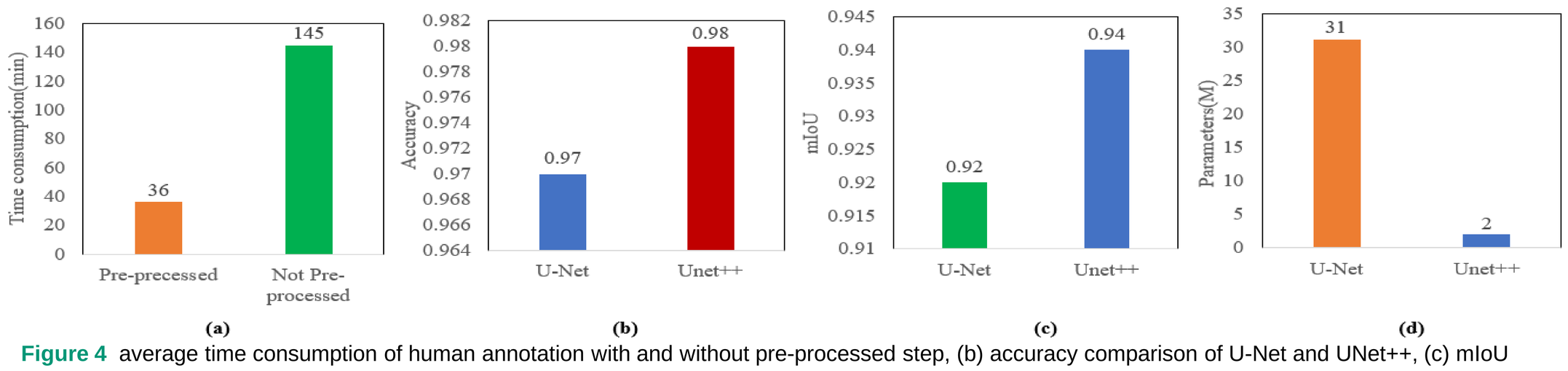

Figure 4 average time consumption of human annotation with and without pre-processed step, (b) accuracy comparison of U-Net and UNet++, (c) mIoU comparison of U-Net and UNet++ and (d) parameters comparison of U-Net and UNet++. UNet++ has higher accuracy and fewer parameters than U-Net.

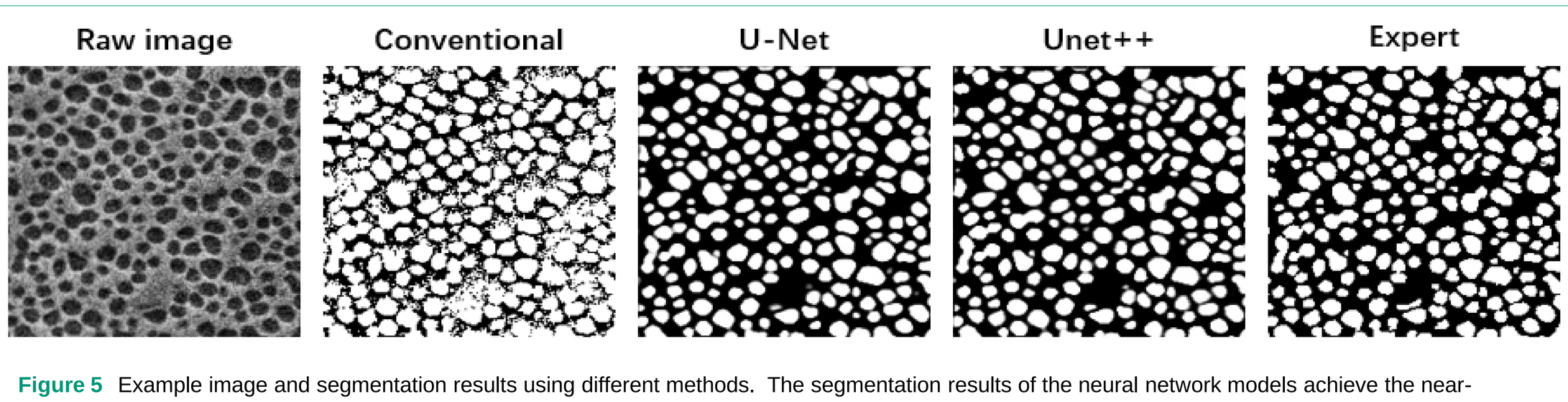

Figure 5 Example image and segmentation results using different methods. The segmentation results of the neural network models achieve the near-expert performance, and outperform the conventional method.

Conclusions

- The microstructure segmentation of superalloy materials prepared by high-throughput experiment is an essential work.
- Deep neural network models, like U-Net, **UNet++**, are more efficient and accurate than conventional approach, which reduce the cost of sample preparation significantly. Meanwhile, **Unet++** performs better than U-Net.