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Semantic segmentation for the analysis of creep voids in metallic materials

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Introduction

- High-temperature metallic materials suffer from creep due to mechanical stresses
- Prolonged creep condition causes material deformation and component failure (Fig. 1)
- Formation of creep voids in material structure is a prime indication of creep phenomenon
- Timely & accurate detection of creep voids helps in better life cycle management of valuable products
- Semantic image segmentation reduces human errors and speeds up the analysis process

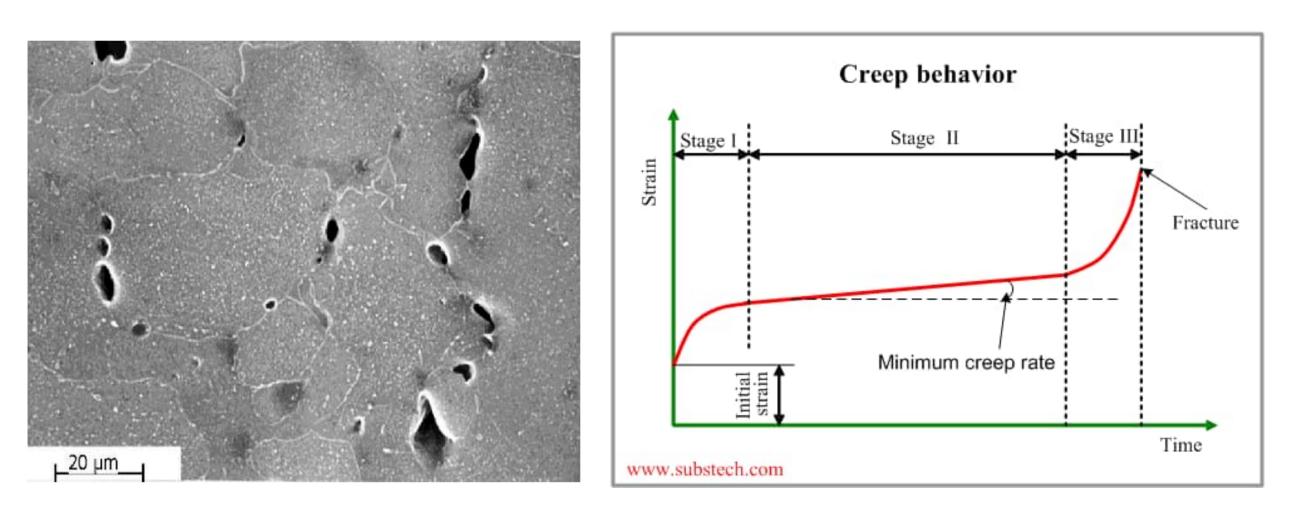


Fig. 1. Creep voids in materials and different stages of creep behavior

Model performance

- Training time about 17 minutes (wall time) for 200 epochs
- Testing IoU score of 0.994 and dice loss of 0.003
- Good agreement between model prediction and ground truth (Fig. 2)
- Information about area fraction (Fig. 3) and number of creep voids in an image (Fig. 4).

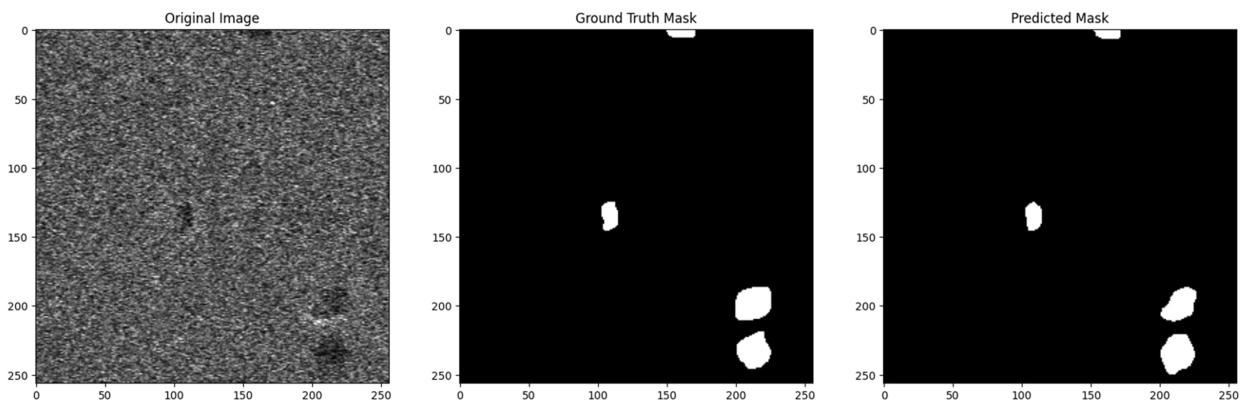
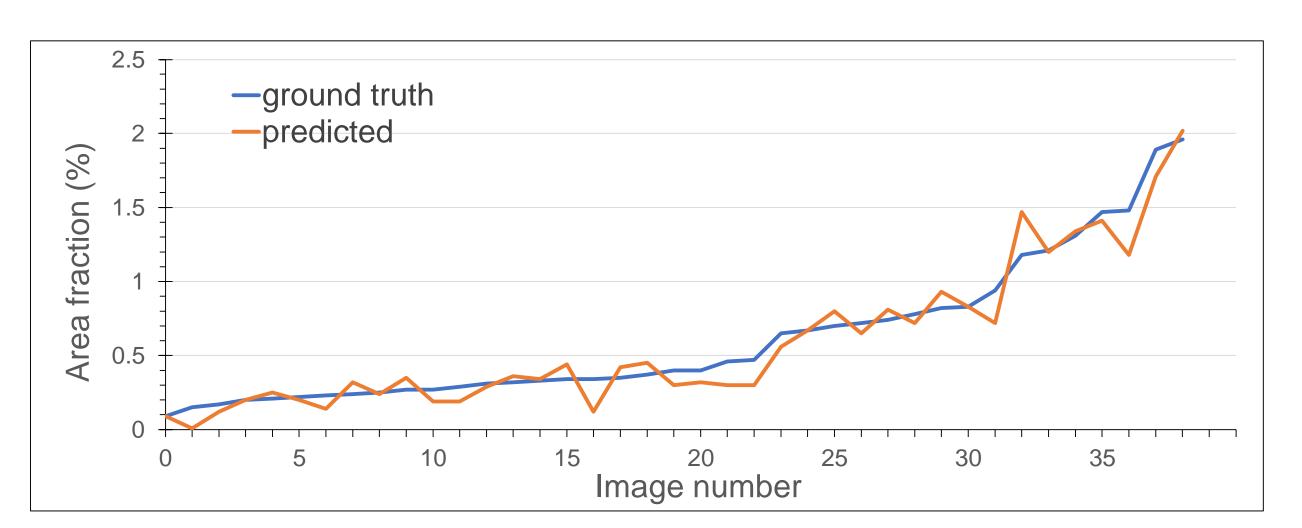


Fig. 2. Comparison between ground truth and predicted masks



Semantic image segmentation

- Assigning a class or label to every pixel of the image
- Information about the location, size, and shape of objects \bullet
- Several applications including medical imaging, object detection, and recognition tasks
- Segmentation models generally consist of an encoder network followed by a decoder network
- Encoder is usually a pre-trained classification network, such as VGG or ResNet
- Decoder projects the discriminative features learned by the encoder into the pixel space, performing classification

Case study – creep voids in copper samples

- SEM images of oxygen-free phosphorous-doped copper sample surfaces
- Our task is to distinguish creep voids (white pixels) from the normal surface (black pixels) (Fig. 2)
- DeepLab-v3+ [2] model built on top of CNN architecture with ResNet encoder pre-trained on ImageNet dataset • Model training 251 (70%), validation 54 (15%), and testing 55 (15%) images

Fig. 3. Area fraction of creep voids, ground truth vs. predicted

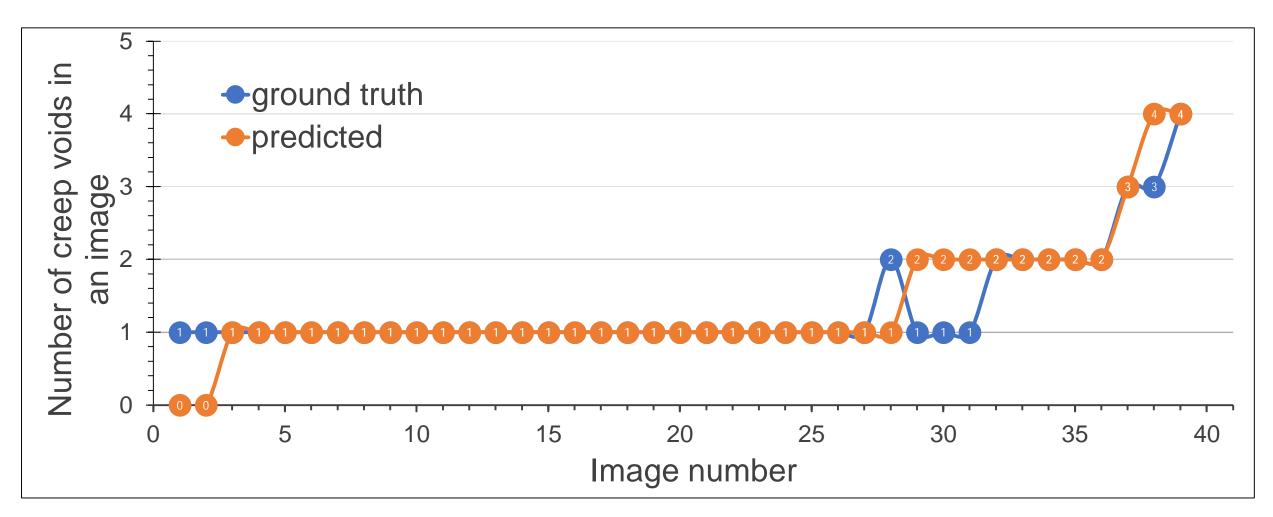


Fig. 4. Number of creep voids in an image, ground truth vs. predicted

Conclusion

- Timely and reliable detection of creep voids is vital for better life cycle management of valuable assets • Knowledge of publicly available pre-trained encoders can be utilized to build new models with few images
- PyTorch-based Segmentation Models [1] library and the Google Colab environment for model implementation

[1] Yakubovskiy, P. 2022. Segmentation Models. Online: <u>https://smp.readthedocs.io/en/latest/index.html</u> [2] Chen, L.C., Zhu, Y. 2018. Semantic Image Segmentation with DeepLab in TensorFlow. Google AI Blog. Available at: https://ai.googleblog.com/2018/03/semantic-image-segmentation-with.html

- Semantic segmentation model accurately segments creep voids in SEM images
- Information about the density and area fraction of creep voids is obtained within a few seconds
- Further work on segmentation of various types of creep voids and generalization of the trained model

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beyond the obvious