Technique of the identification, quantification and measurement of carbon short-fibers using the instance segmentation

J.G. Quijada Pioquinto*, E. Kurkin, E. Minaev, A. Gavrilov

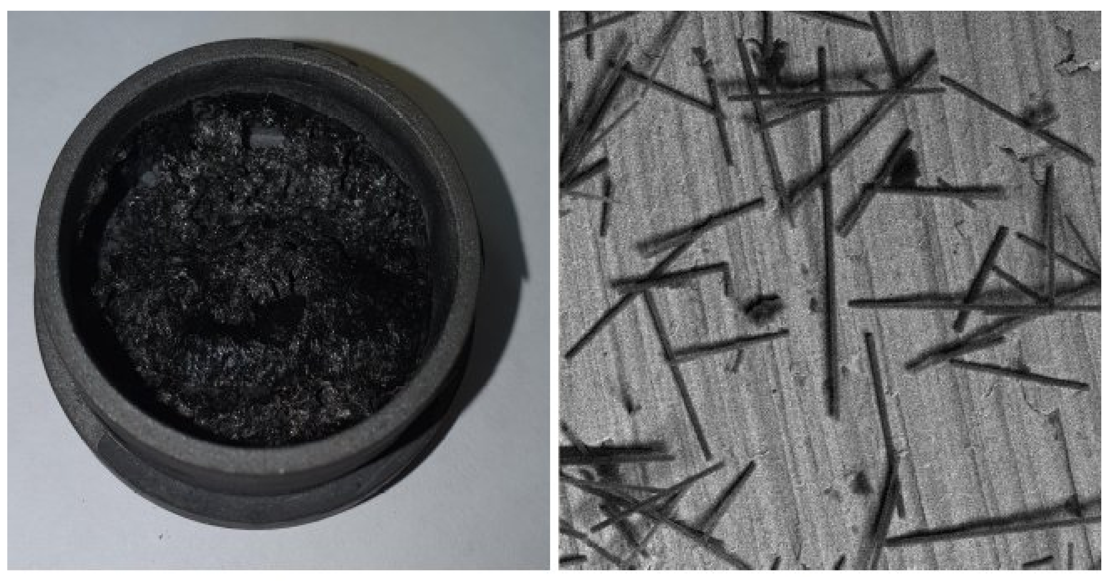
*quijadapiov@gmail.com

INTRODUCTION

This paper demonstrates the use of a neural network with additional training on synthetic data to identify, quantify, and measure short carbon fibers in electron microscope photographs. This task is of importance for the development of a short carbon fiber reinforced polymer material model, which requires precisely counting and measuring the fibers in a sample to determine the structural characteristics of the material [1]. To automate the process of counting and measuring fibers, a neural network architecture called Mask R-CNN was chosen, which is designed to implement computer vision techniques such as: object identification, segmentation and quantification of instances [2]. The selection of this type of architecture was due to the advantages of giving the masks for each instance, which allows obtaining approximate measurements of the fiber geometry. Due to the unavailability of fiber image data, the virtual imaging technique was chosen. Artificial images of short carbon fibers were recreated using the open API NX [3]. A virtual data set with different fiber layouts was created.

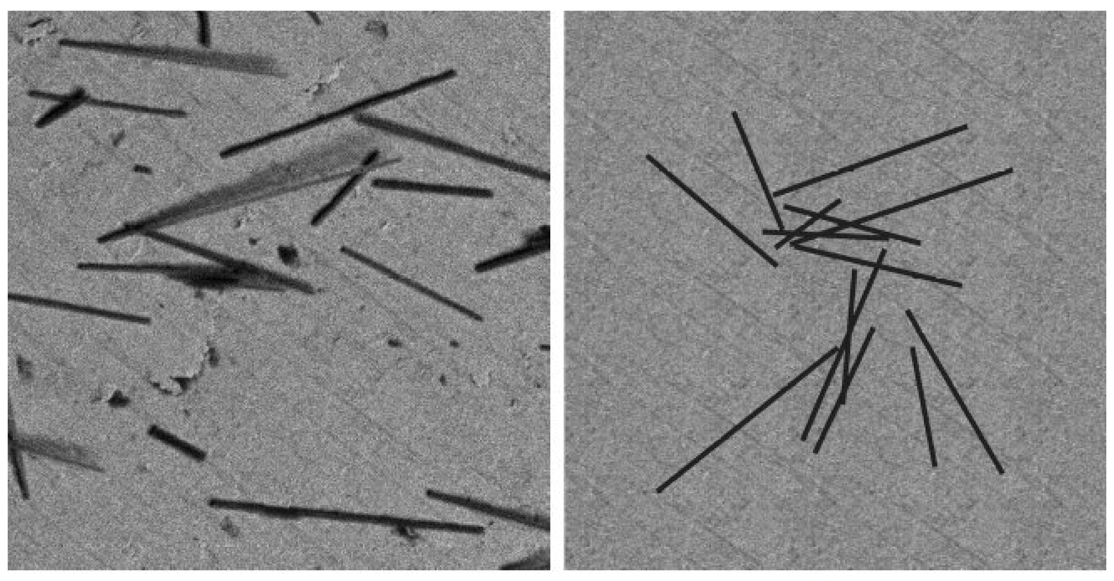
SYNTHETIC DATA GENERATION

For the virtual creation of assembly images of short carbon fibers, the Siemens NX CAD software was used. The virtual dataset consists of a series of images, simulating randomly disperse fibers on a background similar to photographs, and a .json file corresponding to each image in which the coordinates of the fibers, within the picture, are stored. It is worth mentioning that when the identification fiber counting and measurement was done by a person, the photographs can be edited using a filter to clarify the background of the photograph, this in order to have a better contrast between the background and the fibers.



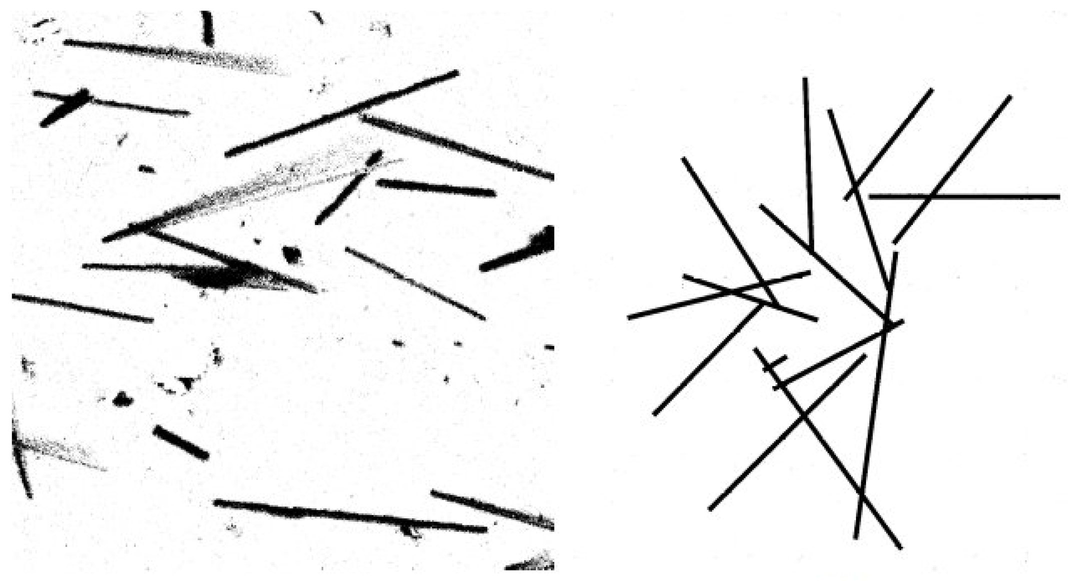
a) b)

Fig. 1. Short fiber extraction from composite: (a) Sample preparation; (b) SEM photo of fibers after matrix burning.



a) b)

Fig. 2. Real (a) and synthetic (b) short fibers.



a) b)

Fig. 3. Real (a) and synthetic (b) filtered short fibers images.

MODEL TRAINING

The hyperparameters selected for Mask R-CNN training are based on the configuration proposed by Abdulla [4]. The loss function is given by the sum of the classification loss, the box regression loss, and the mask generation loss. The length of the fibers was obtained with the help of the boxes and masks generated by the Mask R-CNN network, and considering that each pixel is equivalent to 0.597 micrometers.

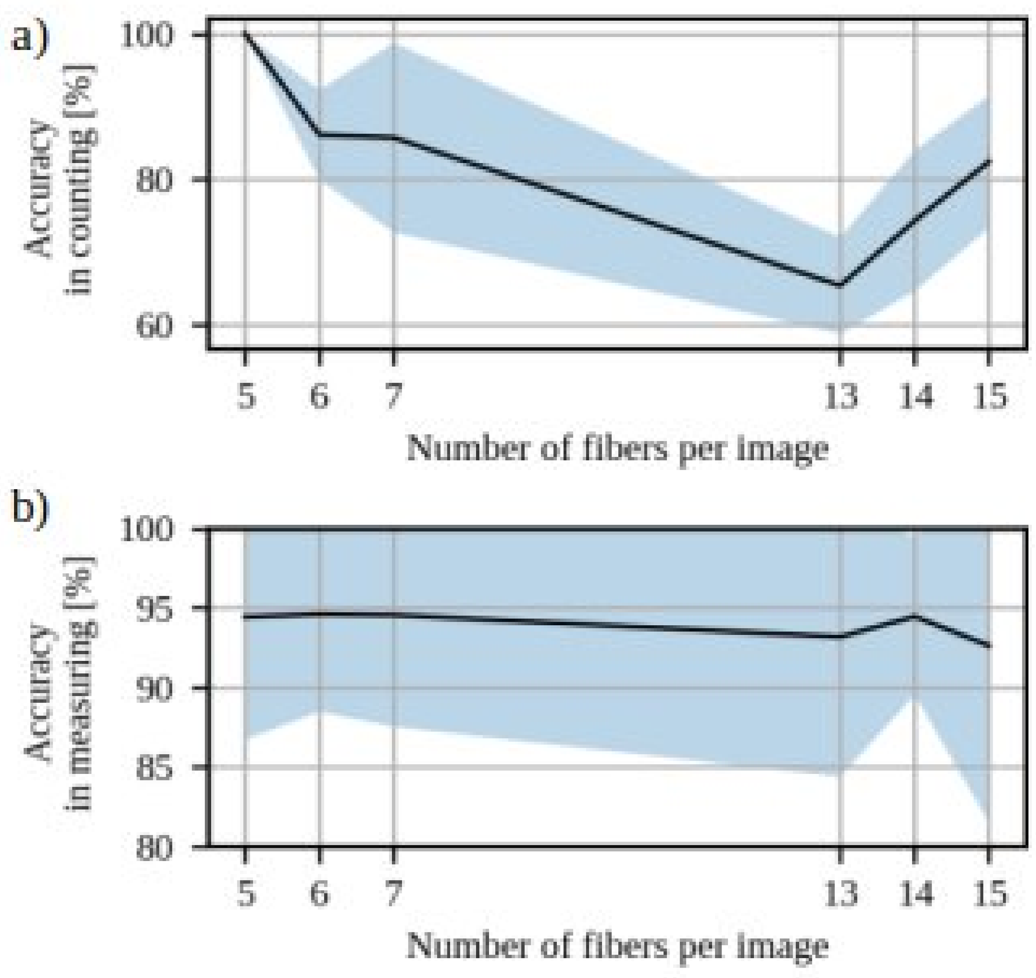


Fig. 4. a) dependence of the accuracy of Mask R-CNN in fiber counting on the number of fibers per image, and b) dependence of the accuracy of Mask R-CNN in fiber measuring on the number of fibers per image, the scatter - by the value of the standard deviation.

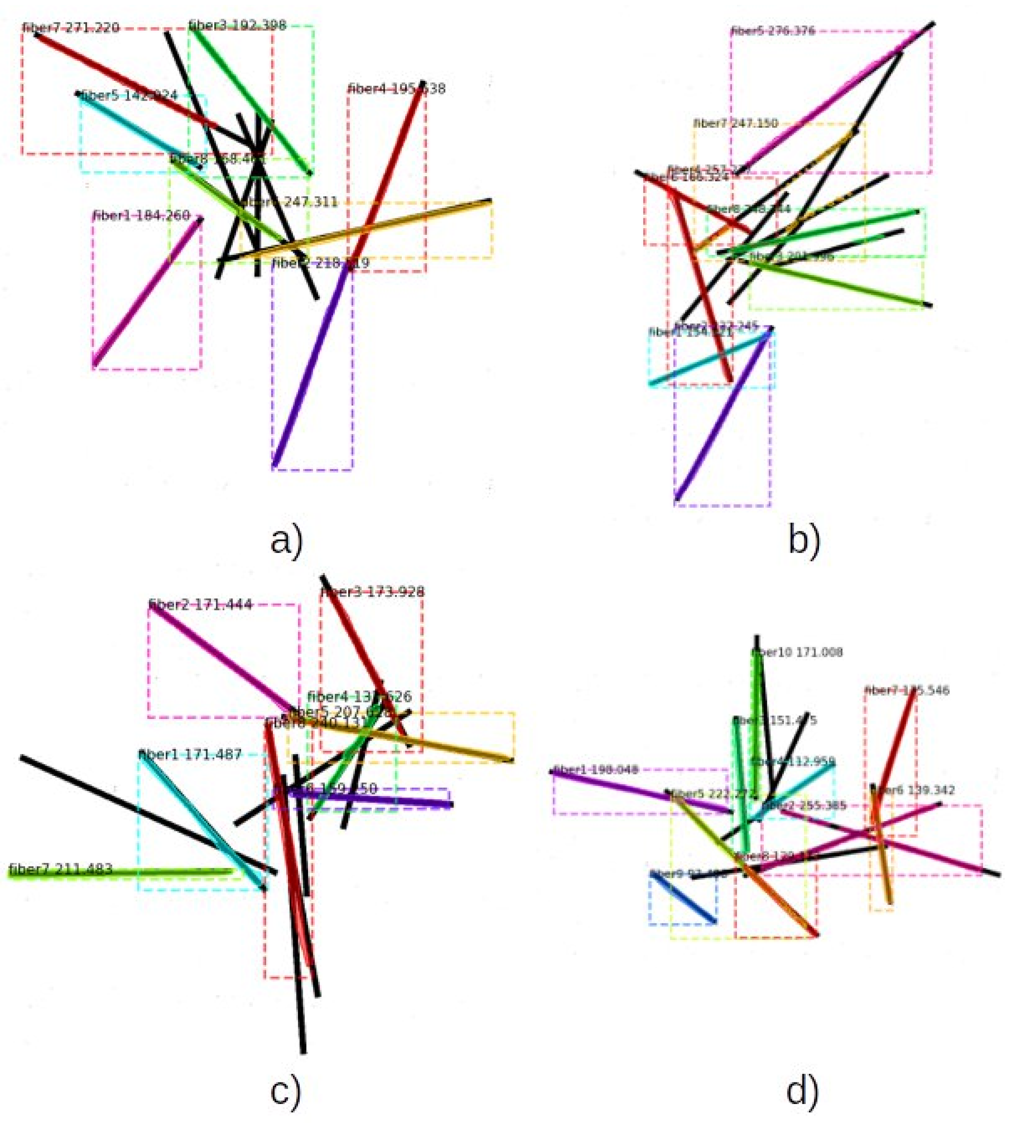


Fig. 5. Samples of images with a higher number of overlapping fibers.

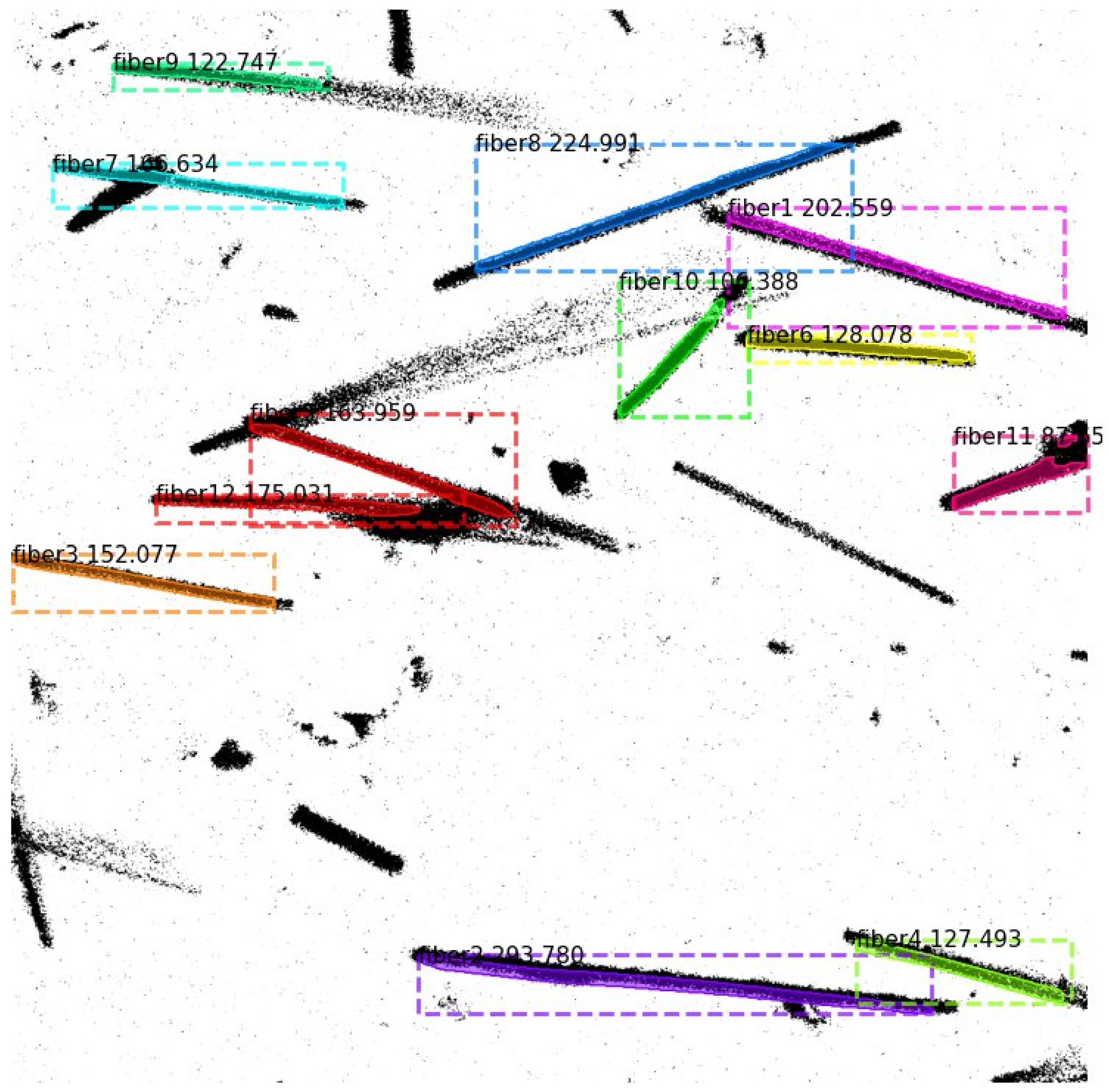


Fig. 6. Testing the Mask R-CNN to predict fibers at the electronic microscope image.

CONCLUSION

The selection of the Mask R-CNN architecture is a good choice to achieve the task of identification, quantification and measurement of short carbon fibers. There are still big challenges to solve, mainly solving the part of detecting instances in very crowded sets and testing with larger populations. In future works it is proposed to give a solution to this problem with which it will be possible to achieve a learning transfer and use Mask R-CNN with real images.

Acknowledgments

The study was financially supported by the Russian Science Foundation, project No. 23-21-00512.

References

[1] Fu, S.Y. Effects of fiber length and fiber orientation distributions on the mechanical properties of short-fiber-reinforced polymers / S.Y. Fu, X. Hu, C.Y. Yue // Journal of the Society of Materials Science Japan. - 1999. - Vol. 48(6). - P. 74-83.

[2] He, K. Mask R-CNN / K. He // In: IEEE International Conference on Computer Vision (ICCV). - 2017.

[3] Siemens NXOpen Programmer's Guide Web Site [Electronic resource]. - Access mode: https://docs.plm.automation.siemens.com/tdoc/nx/10/nx_api/#uid:index (20.10.2022).

[4] Abdulla, W. Mask R-CNN for object detection and instance segmentation on Keras and TensorFlow [Electronic resource] // Github repository. - 2017. – Acces mode: https://github.com/matterport/Mask_RCNN (14.01.2023)

SAMARA UNIVERSITY

34 Moskovskoye shosse,
Samara, 443086
+7 (846) 335-18-26
+7 (846) 335-18-36 (fax)
ssau@ssau.ru
www.ssau.ru