Sensor Networks", *Procedia Computer Science,* vol. 10, pp. 136 – 143, 2012. DOI: 10.1016/j.procs.2012.06.021

[4]. X. He, G. Xie, Y. Jiang, "Online Partial Discharge Detection and Location System Using Wireless Sensor Network", *Energy Procedia,* vol. 12, pp. 420 – 428, 2011. DOI: 10.1016/j.egypro.2011.10.056

[5]. W. Yi, S. S. Gilliland, J. Saniie, "Mobile ultrasonic signal processing system using Android smartphone. Circuits and Systems (MWSCAS)", in *IEEE 56th International Midwest Symposium*, 4-7 August, 2013, pp. 1271-1274. DOI: 10.1109/MWSCAS.2013.6674886.

[6]. Y. Yu, R. Han, X. Zhao, X. Mao, W. Hu, D. Jiao, M. Li, J. Ou, "Initial validation of mobile-structural health monitoring method using smartphones", *International Journal of Distributed Sensor Networks,* February, pp. 1-14, 2015. DOI: 10.1155/2015/274391

[7]. Xie B., Li J., Zhao X. Research on Damage Detection of a 3D Steel Frame Model Using Smartphones. *Sensors,* Vol. 19, no. 3, pp. 745–762, 2019. DOI: 10.3390/s19030745

[8]. Han R., Zhao X., Yu Y., Guan Q., Hu W., Li M., "A Cyber-Physical System for Girder Hoisting Monitoring Based on Smartphones Sensors", *Sensors,* vol. 16, no. 7, pp. 1048–1064, 2016. DOI: 10.3390/s16071048.

[9]. G. Morgenthal, H. Höpfner, "The application of smartphones to measuring transient structural displacements", *Journal of Civil Structural Health Monitoring 2(3-4),* no 2, pp. 149–161, 2012. DOI: 10.1007/s13349-012-0025-0.

[10]. J. Li, B. Xie, X. Zhao, "Measuring the interstory drift of buildings by a smartphone using a feature point matching algorithm", *Structural Control and Health Monitoring*, January, pp.1-17, 2020. DOI: 10.1002/stc.2492

[11]. F. Seraj, N. Meratnia, P. Havinga, "An aggregation and visualization technique for crowd-sourced continuous monitoring of transport infrastructures. Pervasive Computing and Communications Workshops (PerCom Workshops)", *2017 IEEE International Conference on, USA, March*, pp.1-6., 2017. DOI: 10.1109/PERCOMW.2017.7917561.

[12]. В. Петрик, А. Протасов, К. Серый, О. Повшенко, "Використання серійних мобільних пристроїв при проектуванні портативних дефектоскопів", *Вчені записки ТНУ імені В. І. Вернадського. Серія: технічні науки,* том 30 (69), ч. 2, № 6, с.12-16, 2019. DOI: 10.32838/2663-5941/2019.6-2/03.

[13]. V. F. Petryk, A. G. Protasov, R. M. Galagan, A. V. Muraviov, I. I. Lysenko, "Smartphone-Based Automated Non-Destructive Testing Devices", *Devices and Methods of Measurements*, 11(4), pp. 272-278, 2020. doi:10.21122/2220-9506-2020-11-4-272-278.

UDC 004.89

DEEP LEARNING MODELS FOR AUTOMATED OBJECT DETECTION IN INFRARED IMAGES

Momot A. S.
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
E-mail: drewmomot@gmail.com

Thermal imaging cameras have firmly taken their place among the means of computer vision. They perfectly solve tasks assigned to them and allow to create technically and cost-effective systems. Infrared cameras have come a long way from

very expensive devices to a wide-range product with high reliability and affordable price, and they continue to improve every year. Currently, the main areas of application of thermal imaging systems are wide: service and repair of printed circuit boards, household and energy sectors, nondestructive testing of composite materials, technical security equipment, medicine, hunting and military industry, driving.

The feasibility of using thermal imagers is determined by the peculiarities of technical means itself. In security systems, infrared cameras are surveillance devices that are more effective at recognizing objects than traditional video cameras. The recognition quality with a thermal imager does not depend on the time of day. This makes it possible to create systems for round-the-clock monitoring of the protected object. Systems designed for security control are applicable to protect the perimeter of airports, railways, borders, home, farm and other facilities. Analysis of the recorded information can be automated using artificial intelligence technologies [1].

Thermal imaging equipment now provides complete and accurate behavior analysis based on deep learning algorithms. This includes detection of events such as line crossing, intrusion, zone entry, zone exit etc. Intelligent human / vehicle detection can reduce false alarms caused by animals, vibration, falling leaves and other irrelevant events or objects, greatly increasing alarm accuracy [2].

An actual and important task is to determine the architecture of a deep network, which will allow object detection with greatest accuracy. Since modern infrared cameras do not have a high frame rate, calculation speed of deep learning model fades into background. However, for real-time monitoring, the data processing frequency should not be lower than 20-25 Hz. This fact must be taken into account when choosing a suitable model for object recognition. In addition, the task of object detection in infrared images is complicated by the low detail of thermal imprints of these objects, which is associated with physical features of the nature of infrared radiation. Therefore, a deep learning model must be broadly generalizable.

To assess the quality of object detection models, the mAP - mean Average Precision metric is used. This metric calculates the average precision for recall in the range of 0 to 1 for all object classes recognized by the model. For each single class, Average Precision is defined as the area under precision-recall curve. The higher the value of this metric, the less erroneous recognitions model produces on test data.

One of the first models successfully applied in object detection tasks in images was the R-CNN (Regions with CNNs) network [3]. Not the entire image was fed to the network input, but the regions previously selected using the Selective Search algorithm, which presumably contained some objects. A convolutional network used to classify objects depicted in the regions. Nowadays, Faster R-CNN architecture provides mAP value up to 35% at a data processing rate of about 15 frames per second on MS COCO dataset [4]. Such characteristics are a relatively poor indicator for use in thermographic systems. There is also a known modification Mask-RCNN, which allows not only to detect objects, but also to solve the task of image semantic segmentation.

YOLO (You Only Look Once) network architecture has a much higher performance [5]. Main feature: distinguishing objects in one data pass. There are no explicit loops in the YOLO architecture, which makes the network fast. YOLO uses a grid of predefined windows - regions in which objects are classified. On the MS COCO dataset, modern YOLO modifications show up to 44% mAP at a data processing rate of up to 70 frames per second [6]. Networks of this architecture are among the fastest in the task of detecting objects. In this regard, it is recommended to use YOLO models as part of real-time thermographic systems. Fig. 1 shows an example of the application of the YOLOv3 network for human and dog detection in infrared images provided by Flir company.

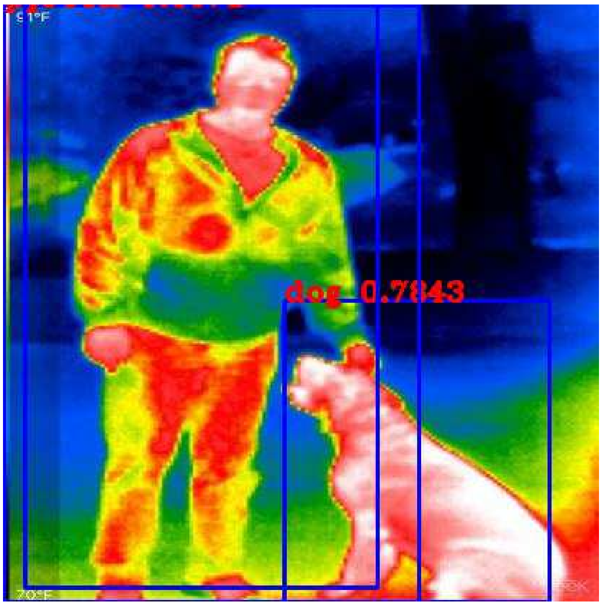

Fig. 1. Person and dog detection on infrared image using YOLOv3 model

EfficientNet is also promising class of new models that resulted from the study of scaling models and balancing the depth and width (number of channels) of network, as well as the resolution of images [7]. The authors of article propose a new compound scaling method that scales the depth / width / resolution evenly with fixed proportions between them. From an existing method called "Neural Architecture Search" for automatically generating new networks and their own scaling method, the authors derive a new class of models called EfficientNets [8]. The latest modification, called EfficientDet, consists of EfficientNet as a base, to which a feature pyramid layer called BiFPN is added, followed by a "standard" class / frame computation network. This network shows mAP up to 46% at a data processing rate of about 35 frames per second on the MS COCO set [6].

Given the rapid development of deep learning, these models are relevant only at the time of this writing. However, considered classes of deep network models have been leaders in the field of object detection for a long time. Therefore, these models are recommended for consideration as algorithms for infrared images processing. Since in most of considered areas of application of thermographic systems,

recognition accuracy is higher priority, rather than speed, EfficientDet models are of particular interest. It should be noted that comparison of the efficiency of these networks was carried out on a set of images of the visible light spectrum. Therefore, the main task for further research is to compare the mentioned architectures on a set of infrared images to obtain quantitative estimates of their work quality.

Keywords: deep learning, object detection, infrared images.

References

[1]. R. M. Galagan and A. S. Momot, "The use of ART-2 neural network for processing information signals of non-destructive testing," in *Proceedings of the IEEE First Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, Kiev, pp. 981-985, 2017.

[2]. Z. Zhao, X. Fan, G. Xu, L. Zhang, Y. Qi and K. Zhang, "Aggregating Deep Convolutional Feature Maps for Insulator Detection in Infrared Images", *IEEE Access*, vol. 5, pp. 21831-21839, 2017.

[3]. R. Girshick, J. Donahue and J. Malik, "Rich feature hierarchies for accurate object detection and semantic segmentation", *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 580-587, 2017.

[4]. M. Derakhshani, S. Masoudnia, A. Shaker and O. Mersa, "Assisted excitation of activations: A learning technique to improve object detectors", *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 9201-9210, 2019.

[5]. J. Du, "Understanding of Object Detection Based on CNN Family and YOLO", *Journal of Physics: Conference Series*, vol. 1004, pp. 012029, 2018. Available: 10.1088/1742-6596/1004/1/012029.

[6]. A. Bochkovskiy, W. Chien-Yao and M. Hong-Yuan, "Yolov4: Optimal speed and accuracy of object detection", arXiv preprint arXiv:2004.10934, 2020.

[7]. T. Mingxing and Q. Le, "Efficientnet: Rethinking model scaling for convolutional neural networks", International Conference on Machine Learning. PMLR, pp. 6105-6114, 2019.

[8]. T. Mingxing, R. Pan and Q. Le, "Efficientdet: Scalable and efficient object detection", in *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 10781-10790, 2020.

УДК 620.179.14

РОБОТИЗОВАНА СИСТЕМА АВТОМАТИЧНОГО КОНТРОЛЮ СТРУКТУРИ МАТЕРІАЛУ МЕТОДОМ ВИЩИХ ГАРМОНІК

Баженов В. Г., Калениченко Ю. О., Рацебарський С. С.
Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського», Київ, Україна
E-mail: vgbazhenov@gmail.com

Контроль структури матеріалів є актуальною задачею, бо зміна їх структури, наприклад під дією втоми матеріалу, під дією високотемпературного або механічного впливу на деяких локальних ділянках може призвести до подальшої появи дефектів з ознаками руйнування виробу.

На кафедрі ПСНК «КПІ ім. Ігоря Сікорського» авторами було розроблено роботизовану цифрову систему автоматичного контролю структури матеріалів методом вищих гармонік. До складу системи входять: 1-цифровий