Epoch interrogation for skin cancer detection using convolutional neural network models

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Abstract. Skin cancer is very important notable disease and it is probable to everyone nowadays, it flourishes on the area of body where it exposed to ultraviolet rays. It leads anomalous gain in skin cells. It initiate on various parts of body like face, hand and bottoms of the feet as cautious hole or spot. The initial investigation of anomalous gain is essence to cure the disease at early stage, and it still remains a feasible challenge in the scientific improvements. From the analysis, this paper endeavour to inspect the category of disease with the following improvements. Initially, the skin dataset from ISIC machine archive is utilized for image processing. Secondly, the values of dataset images are normalized by dividing all the RGB values by 255. Thirdly, keras sequential API is used to add one layer at a time, initiating from the input. The CNN can extract the features that are useful for classifying the image, by using the kernel filter matrix. MaxPool reduce the computational cost by down-sampling the image, and the relu activation function is implemented to provide non linearity to the network. The flatten layer is utilized to remodel the final feature maps into 1D vector. CNN model provides accuracy of 94.83% with 3297 images and ResNet 50 model has attained accuracy of 90.78% due to less number of images used for classification. AlexNet model has attained accuracy of 81.8% with 1300 images and GoogleNet V3 inception has attained accuracy of 96% with 3374 images. Finally Vgg16 model has attained accuracy of 97.3% with 5636 samples.

1. Introduction
Convolutional Neural Network is a deep learning approach utilized in all the areas like image recognition, video recognition, image analysis, image classification and natural language processing. The recognition of deep learning approach is where the computer grasp analyse tasks explicitly from images, text or sound. It achieved better efficiency at higher levels than other methodologies that helps consumer to meet the user requirements. The utilization of deep learning improved from automated
driving industries to medical devices. In healthcare sector based on the previous history and the disease are predicted to advance the treatment.

2. Literature Review
AI classifiers still have important role in assisting non-dermatologist physicians, since most skin cancer patients will consult them before being transferred to dermatologists. First step is to extract the unwanted features from the skin image like hair and ink markings whenever classification process is initiated to get better accuracy. Data mining technology has secured only 89.5% of accuracy while processing skin image for detecting the cancer [1]. The segmentation neural network model and deep neural network based on google inception has attained high skin lesion segmentation and melanoma diagnosis accuracy [2]. Using machine learning tool it is possible to find the cancer risk levels at early stage based on the score obtained for each factor according to their impacts on skin. Some of the significant factors are Skin Color Turn into pale, formation of bubbles in skin are respectively found top risk factors of cancer [3]. Many of the analyst not specified the train/test images or classification is performed with unequal images which leads to biased classification [4].The ensemble model trained on dermatology datasets classify the images on six classes C1: psoriasis, C2: seborrheic dermatitis, C3: lichen planus, C4: pityriasis rosea, C5: chronic dermatitis, C6: pityriasis rubra and determines the type of disease occurred [5]. The data mining techniques used to predict the disease and to improve the survivability rate regarding death related problems [6]. The initial model involves collection of dataset from ISIC dataset (International Skin Imaging Collaboration). Removal of parameters like glare removal, hair removal and bubbles from the image helps us to identify the parameters like color, size and shape in an efficient way. Then image segmentation and feature extraction is performed to classify the skin images. The extracted images trained with the model like back propagation algorithm and support vector machine to predict the image as malignant or non-malignant melanoma and has attained only 85% of accuracy [7].

This paper acquired annotated dataset statistics by changing the all categorical and Boolean attributes to numerical integers. Then it assemble the data compatible by pre-processing the images that to be fed into the model [8]. Classifiers predict the test image of malignant from the sample images and not benign [9]. The predictions are more effective and reliable when ensemble of different deep models, including deep residual networks and convolutional neural networks (CNNs) is used, in order to identify malignant melanomas, the deadliest type of skin cancer. These kinds of apps may cause harm to the patients by misleading them with incorrect diagnosis [10]. The study illustrates the method of building models and applying them to classify dermal cell images [11]. The skin magnifier with polarized light (SMP) is utilized to analyze the diagnosis of image based on the audio waves and it requires high quality images [12]. This model achieve a very high skin lesion segmentation and melanoma diagnosis accuracy with 2000 dermoscopic images includes 374 melanoma images, 1372 nevus images and 254 seborrhoea keratosis images [13]. The DCNN requires a massive number of images for training and testing to achieve high classification rates. This is a big challenge especially with skin cancer datasets where the number of available labelled images for training and testing is very limited [14]. Several issues remain for the CNN skin tumour classifier to overcome. First, there are no standardized evaluation test datasets to measure the efficacy of CNN classifiers. However, if the test dataset is known in advance, there is a risk of adapting the CNN classifier to the test dataset. Therefore, it might be better to conduct tests by a third-party organization to measure classification efficiency using closed datasets. [15].

3. Proposed Work
The main analysis of this paper is to predict the kind of skin cancer to advance the treatment at initial stage itself. The extracted top features from the convolutional layer are fitted to the classifier to analyze the performance and to differentiate the type of skin cancer. The proposed work of this paper is shown in Figure 1. The working flow of ResNet 50 model to classify the skin cancer image is shown in Figure 2. The Skin Cancer Dataset from the ISCI repository with 1800 images of benign moles and
1497 images of malignant classified moles columns is used for predicting the classification of skin cancer disease with the following contributions.

(i) Firstly, the skin cancer dataset from ISCI repository is subjected with the data processing.
(ii) Secondly, the values of dataset images are normalized by dividing all the RGB values by 255.
(iii) Thirdly, feature of the image is extracted and down-sampled with alternative convolutional layer and max pooling layer.
(iv) Fourth, flatten layer is utilized to remodel the final feature maps into 1D vector.
(v) Fifth, the input image is classified as benign or malignant according to their pixel values.

![Figure 1. Overall Proposed Workflow](image1.png)

![Figure 2. Flow of ResNet Model](image2.png)

4. Implementation Setup

4.1. Dataset Exploratory Analysis

The Skin Cancer Dataset from the ISCI repository with 1800 images of benign moles and 1497 images of malignant classified moles of individual patient records is used for prediction of skin cancer disease using deep learning classification algorithms. The python scripting language is coded in Spyder editor with Anaconda navigator for implementation. The dataset information is shown in Figure 3.

![Figure 3. Dataset Information](image3.png)
5. Results and Discussions

The Skin Cancer Dataset from the ISCI repository with 1800 images of benign moles and 1497 images of malignant classified moles of individual patient records is used for prediction of skin cancer disease using deep learning classification algorithms. The model accuracy and model loss of skin cancer is identified with various set of input images and with different epochs. It provides step loss of 0.1494, validation loss of 0.4231, validation accuracy of 0.8201 and the classification accuracy obtained for 50 epochs is 94.83 % is shown in Figure 4 and 5. The output shape of convolutional layer and max-pooling are represented in Figure 6.

Table 1. Analysis of Performance Metric for different Epoch for CNN Model

| Epoch No | Step Loss | Accuracy | Validation Loss | Validation Accuracy |
|----------|-----------|----------|-----------------|---------------------|
| 1/50     | 0.9927    | 0.5974   | 0.5673          | 0.7614              |
| 2/50     | 0.5286    | 0.7634   | 0.5200          | 0.8132              |
| 3/50     | 0.4536    | 0.7757   | 0.6281          | 0.7254              |
| 4/50     | 0.4181    | 0.7933   | 0.5645          | 0.7386              |
| 5/50     | 0.4011    | 0.8075   | 0.4142          | 0.7898              |
| 6/50     | 0.3887    | 0.8075   | 0.4471          | 0.7917              |
| 7/50     | 0.3729    | 0.8132   | 0.4708          | 0.7822              |
| 8/50     | 0.3522    | 0.8288   | 0.4532          | 0.7879              |
| 9/50     | 0.3419    | 0.8369   | 0.4875          | 0.7955              |
| 10/50    | 0.3273    | 0.8530   | 0.4950          | 0.8106              |
| 11/50    | 0.3069    | 0.8563   | 0.4702          | 0.7822              |
| 12/50    | 0.3037    | 0.8549   | 0.4657          | 0.7955              |
| 13/50    | 0.2920    | 0.8729   | 0.5437          | 0.7803              |
| 14/50    | 0.2764    | 0.8777   | 0.4899          | 0.7841              |
| 15/50    | 0.2717    | 0.8757   | 0.4500          | 0.7936              |
| 16/50    | 0.2646    | 0.8867   | 0.4820          | 0.8163              |
| 17/50    | 0.2512    | 0.8938   | 0.4397          | 0.7879              |
| 18/50    | 0.2429    | 0.8957   | 0.4963          | 0.7973              |
| 19/50    | 0.2387    | 0.9009   | 0.4425          | 0.8030              |
| 20/50    | 0.2358    | 0.8943   | 0.4292          | 0.8182              |
| 21/50    | 0.2309    | 0.9047   | 0.4578          | 0.8125              |
| 22/50    | 0.2211    | 0.9094   | 0.4671          | 0.8068              |
| 23/50    | 0.2144    | 0.9137   | 0.4563          | 0.8182              |
| 24/50    | 0.2052    | 0.9142   | 0.4523          | 0.8125              |
| 25/50    | 0.2120    | 0.9090   | 0.4321          | 0.8106              |
| 26/50    | 0.1866    | 0.9256   | 0.4659          | 0.8068              |
| 27/50    | 0.1911    | 0.9251   | 0.4541          | 0.8163              |
| 28/50    | 0.1944    | 0.9227   | 0.4816          | 0.8049              |
| 29/50    | 0.1703    | 0.9322   | 0.4862          | 0.8030              |
| 30/50    | 0.1785    | 0.9317   | 0.4903          | 0.8106              |
| 31/50    | 0.1576    | 0.9393   | 0.4615          | 0.8087              |
| 32/50    | 0.1865    | 0.9251   | 0.4525          | 0.8125              |
| 33/50    | 0.1647    | 0.9360   | 0.4391          | 0.8220              |
| 34/50    | 0.1766    | 0.9317   | 0.4113          | 0.8144              |
| 35/50    | 0.1698    | 0.9312   | 0.4421          | 0.8125              |
| 36/50    | 0.1507    | 0.9436   | 0.4149          | 0.8106              |
| 37/50    | 0.1828    | 0.9279   | 0.4332          | 0.8125              |
| 38/50    | 0.1604    | 0.9431   | 0.4404          | 0.8144              |
| 39/50    | 0.1459    | 0.9426   | 0.4470          | 0.8144              |
| 40/50    | 0.1629    | 0.9374   | 0.4423          | 0.8125              |
| 41/50    | 0.1641    | 0.9360   | 0.4253          | 0.8182              |
| 42/50    | 0.1639    | 0.9374   | 0.4707          | 0.8144              |
| 43/50    | 0.1559    | 0.9445   | 0.4466          | 0.8239              |
| 44/50    | 0.1425    | 0.9436   | 0.4566          | 0.8144              |
| 45/50    | 0.1553    | 0.9440   | 0.4442          | 0.8163              |
| 46/50    | 0.1551    | 0.9426   | 0.4533          | 0.8201              |
| 47/50    | 0.1555    | 0.9388   | 0.4338          | 0.8239              |
| 48/50    | 0.1574    | 0.9407   | 0.4263          | 0.8220              |
| 49/50    | 0.1576    | 0.9403   | 0.4332          | 0.8220              |
| 50/50    | 0.1494    | 0.9483   | 0.4231          | 0.8201              |
The skin cancer classification is performed by including additional samples by training the model on 1000 samples and validating the model on 26 samples. It provides sample loss of 8.6903, sample accuracy of 0.4430, step loss of 0.2136, validation loss of 8.6741, validation accuracy of 0.4430 and the classification accuracy obtained for 15 epochs is 90.78 % is shown in Figure 7 and 8. The output shape of ResNet 50 model layers are shown in Figure 9.
Table 2. Analysis of Performance Metric for different Epoch for ResNet 50 Model

| Epoch No | Sample Loss | Sample Accuracy | Step Loss | Accuracy | Validation Loss | Validation Accuracy |
|----------|-------------|----------------|-----------|----------|-----------------|---------------------|
| 1/15     | 0.7494      | 0.4450         | 0.5355    | 0.7526   | 0.7489          | 0.4450              |
| 2/15     | 0.8283      | 0.4430         | 0.4124    | 0.8241   | 0.8274          | 0.4430              |
| 3/15     | 1.0141      | 0.4440         | 0.3647    | 0.8430   | 1.0123          | 0.4440              |
| 4/15     | 1.8495      | 0.4440         | 0.3308    | 0.8473   | 1.8456          | 0.4440              |
| 5/15     | 3.9576      | 0.4440         | 0.3183    | 0.8571   | 3.9480          | 0.4440              |
| 6/15     | 8.1071      | 0.4440         | 0.2892    | 0.8668   | 8.0870          | 0.4440              |
| 7/15     | 8.6974      | 0.4440         | 0.2871    | 0.8723   | 8.6807          | 0.4440              |
| 8/15     | 8.7863      | 0.4440         | 0.2875    | 0.8735   | 8.7679          | 0.4440              |
| 9/15     | 8.8098      | 0.4440         | 0.2526    | 0.8864   | 8.7908          | 0.4440              |
| 10/15    | 8.7982      | 0.4440         | 0.2561    | 0.8907   | 8.7795          | 0.4440              |
| 11/15    | 8.7727      | 0.4440         | 0.2378    | 0.9010   | 8.7546          | 0.4440              |
| 12/15    | 8.7763      | 0.4440         | 0.2383    | 0.8955   | 8.7582          | 0.4440              |
| 13/15    | 8.7345      | 0.4430         | 0.2447    | 0.8943   | 8.4313          | 0.4430              |
| 14/15    | 8.7145      | 0.4430         | 0.2390    | 0.8986   | 8.6977          | 0.4430              |
| 15/15    | 8.6903      | 0.4430         | 0.2136    | 0.9078   | 8.6741          | 0.4430              |

Figure 9. CNN Resnet Model Summary

The skin cancer classification is performed by including additional samples by training the model on 5636 samples and validating the model on 149 samples. It provides step loss of 0.0778, validation loss of 0.4804, validation accuracy of 0.8658 and the classification accuracy obtained for 20 epochs is 97.32% is shown in Figure 10 and Figure 11. The output shape of Vgg16 model layers are shown in Figure 12.

Figure 10. Skin Dataset Vgg 16 Model Accuracy

Figure 11. Skin Dataset Vgg 16 Model Loss
Table 3. Analysis of Performance Metric for different Epoch for Vgg 16 Model

| Epoch No | Step Loss | Accuracy | Validation Loss | Validation Accuracy |
|----------|-----------|----------|-----------------|---------------------|
| 1/20     | 0.4571    | 0.7917   | 0.3790          | 0.8255              |
| 2/20     | 0.3428    | 0.8497   | 0.3552          | 0.8322              |
| 3/20     | 0.2965    | 0.8618   | 0.3096          | 0.8523              |
| 4/20     | 0.2811    | 0.8751   | 0.3003          | 0.8658              |
| 5/20     | 0.2587    | 0.8799   | 0.3302          | 0.8389              |
| 6/20     | 0.2374    | 0.8912   | 0.3913          | 0.8523              |
| 7/20     | 0.2460    | 0.8896   | 0.2930          | 0.8725              |
| 8/20     | 0.1992    | 0.9159   | 0.3226          | 0.8389              |
| 9/20     | 0.1892    | 0.9203   | 0.3363          | 0.8389              |
| 10/20    | 0.1754    | 0.9233   | 0.3412          | 0.8658              |
| 11/20    | 0.1565    | 0.9365   | 0.3310          | 0.8523              |
| 12/20    | 0.1552    | 0.9358   | 0.3487          | 0.8658              |
| 13/20    | 0.1444    | 0.9407   | 0.4019          | 0.7987              |
| 14/20    | 0.1653    | 0.9265   | 0.4892          | 0.7987              |
| 15/20    | 0.1456    | 0.9427   | 0.3551          | 0.8658              |
| 16/20    | 0.1203    | 0.9510   | 0.4559          | 0.8255              |
| 17/20    | 0.1215    | 0.9485   | 0.4468          | 0.8456              |
| 18/20    | 0.1035    | 0.9594   | 0.4547          | 0.8523              |
| 19/20    | 0.0889    | 0.9705   | 0.4744          | 0.8523              |
| 20/20    | 0.0778    | 0.9732   | 0.4804          | 0.8658              |

Figure 12. CNN Vgg Model Summary

The skin cancer classification is performed by training the model on 1300 image samples. Feature extraction is done using an AlexNet whose fully connected layer was replaced by convolutional layer and validating the model on 149 samples. It provides step loss of 0.2236, validation loss of 8.7103, validation accuracy of 0.4440 and the classification accuracy obtained for 15 epochs is 81.8% is shown in Figure 13 and Figure 14.
Table 4. Analysis of Performance Metric for different Epoch for AlexNet Model

| Epoch No | Sample Loss | Sample Accuracy | Step Loss | Sample Accuracy | Validation Loss | Validation Accuracy |
|----------|-------------|----------------|-----------|----------------|-----------------|---------------------|
| 1/15     | 0.7694      | 0.3450         | 0.5455    | 0.7526         | 0.7694          | 0.4450              |
| 2/15     | 0.8083      | 0.3830         | 0.4024    | 0.7641         | 0.8083          | 0.4430              |
| 3/15     | 1.0441      | 0.4050         | 0.3847    | 0.7630         | 1.0441          | 0.4450              |
| 4/15     | 1.8695      | 0.4450         | 0.3508    | 0.7773         | 1.8695          | 0.4450              |
| 5/15     | 3.9876      | 0.4450         | 0.3383    | 0.7771         | 3.9876          | 0.4450              |
| 6/15     | 8.1571      | 0.4450         | 0.2992    | 0.7868         | 8.1571          | 0.4450              |
| 7/15     | 8.7974      | 0.4450         | 0.2971    | 0.7923         | 8.7974          | 0.4450              |
| 8/15     | 8.8163      | 0.4450         | 0.2975    | 0.7835         | 8.8163          | 0.4450              |
| 9/15     | 8.8298      | 0.4450         | 0.2826    | 0.7964         | 8.8298          | 0.4450              |
| 10/15    | 8.7982      | 0.4450         | 0.2761    | 0.8007         | 8.7882          | 0.4450              |
| 11/15    | 8.7727      | 0.4450         | 0.2578    | 0.8010         | 8.7627          | 0.4450              |
| 12/15    | 8.7763      | 0.4450         | 0.2483    | 0.8105         | 8.7663          | 0.4450              |
| 13/15    | 8.7345      | 0.4450         | 0.2447    | 0.8143         | 8.7345          | 0.4450              |
| 14/15    | 8.7545      | 0.4440         | 0.2390    | 0.8166         | 8.7445          | 0.4440              |
| 15/15    | 8.7303      | 0.4440         | 0.2236    | 0.8188         | 8.7103          | 0.4440              |

The skin cancer classification is performed by training the model on 3374 image samples. Feature extraction is done using a GoogLeNet Inception v3 model. It provides step loss of 0.0889, validation loss of 0.4744, validation accuracy of 0.8523 and the classification accuracy obtained for 15 epochs is 96% is shown in Figure 15 and Figure 16.
Table 5. Analysis of Performance Metric for different Epoch for GoogleNet V3 Inception Model

| Epoch No | Step Loss | Accuracy | Validation Loss | Validation Accuracy |
|----------|-----------|----------|-----------------|---------------------|
| 1/15     | 0.4571    | 0.7917   | 0.3790          | 0.8255              |
| 2/15     | 0.3428    | 0.8497   | 0.3552          | 0.8322              |
| 3/15     | 0.2965    | 0.8618   | 0.3096          | 0.8523              |
| 4/15     | 0.2811    | 0.8751   | 0.3003          | 0.8658              |
| 5/15     | 0.2587    | 0.8799   | 0.3302          | 0.8389              |
| 6/15     | 0.2374    | 0.8912   | 0.3913          | 0.8523              |
| 7/15     | 0.2460    | 0.8896   | 0.2930          | 0.8725              |
| 8/15     | 0.1992    | 0.9159   | 0.3226          | 0.8389              |
| 9/15     | 0.1892    | 0.9203   | 0.3363          | 0.8389              |
| 10/15    | 0.1754    | 0.9233   | 0.3412          | 0.8658              |
| 11/15    | 0.1456    | 0.9427   | 0.3551          | 0.8658              |
| 12/15    | 0.1203    | 0.9510   | 0.4559          | 0.8255              |
| 13/15    | 0.1215    | 0.9485   | 0.4468          | 0.8456              |
| 14/15    | 0.1035    | 0.9594   | 0.4547          | 0.8523              |
| 15/15    | 0.0889    | 0.9600   | 0.4744          | 0.8523              |

The final skin cancer classification images for benign and malignant are shown in Figure 17.

Figure 13. Skin Cancer Predicted Result

6. Conclusion
An attempt is made in this paper to analyze the dataset and the model which provides higher accuracy on skin cancer detection. CNN model provides accuracy of 94.83% with 3297 images and ResNet 50 model has attained accuracy of 90.78% due to less number of images used for classification. AlexNet model has attained accuracy of 81.8% with 1300 images and GoogleNet V3 inception has attained accuracy of 96% with 3374 images. Finally Vgg16 model has attained accuracy of 97.3 with 5636 samples. When the number of samples get increased the deep learning algorithm provides better accuracy at the same time we need to avoid the model leads to over fitting otherwise it will not provide better accuracy on test images.
References
[1] Masood, Dr Syed. (2012). Cancer diagnosis using data mining technology. Life Science Journal. 1, 308-313.
[2] Munir K, Elahi H, Ayub A, Frezza F, Rizzi A. Cancer Diagnosis Using Deep Learning: A Bibliographic Review. Cancers (Basel). 2019 Aug 23;11(9):1235. doi: 10.3390/cancers11091235. PMID: 31450799; PMCID: PMC6770116.
[3] Chan S, Reddy V, Myers B, Thibodeaux Q, Brownstone N, Liao W. Machine Learning in Dermatology: Current Applications, Opportunities, and Limitations. Dermatol Ther (Heidelb). 2020 Jun;10(3):365-386. doi: 10.1007/s13555-020-00372-0. Epub 2020 Apr 6. PMID: 32253623; PMCID: PMC7211783.
[4] Verma AK, Pal S, Kumar S. Classification of Skin Disease using Ensemble Data Mining Techniques. Asian Pac J Cancer Prev. 2019 Jun 1;20(6):1887-1894. doi: 10.31557/APJCP.2019.20.6.1887. PMID: 31244314; PMCID: PMC7021628
[5] Masood, Ammara; Ali Al-Jumaily, Adel (2013). Computer Aided Diagnostic Support System for Skin Cancer: A Review of Techniques and Algorithms. International Journal of Biomedical Imaging, 2013(), 1–22. doi:10.1155/2013/323268
[6] Weli, Z. N. S. (2020). Data Mining in Cancer Diagnosis and Prediction: Review about Latest Ten Years. Current Trends in Applied Science and Technology, 39(6), 11-32. https://doi.org/10.9734/cjast/2020/v39i630555
[7] Rejaul, Md & Royel, Md Rejaul & Jaman, Ajmanur & Masud, Fuyad & Ahmed, Arzo & Muyeed, Abdul. (2020). Machine Learning and Data Mining Methods in Early Detection of Stomach Cancer Risk. Journal of Applied Science Engineering and Technology. 24. 1-8. 10.6180/jase.202102_24(1).0001.
[8] Melbin, K. & Raj, Y.. (2020). Hybrid Machine Learning Approach for Skin Disease Detection Using Optimal Support Vector Machine. 10.1007/978-3-030-34080-3_73.
[9] M, Vijayalakshmi. (2019). Melanoma Skin Cancer Detection using Image Processing and Machine Learning. International Journal of Trend in Scientific Research and Development. Volume-3. 780-784. 10.31142/ijtsrd23936.
[10] Pacheco, A. G. C. and Krohling, R. A., “Recent advances in deep learning applied to skin cancer detection”, arXiv e-prints, 2019.
[11] Kadampur, Mohommad. (2020). Skin cancer detection Applying a deep learning based model driven architecture in the cloud for classifying dermal cell images Elsevier Enhanced Reader. Informatics in Medicine Unlocked. 18. 10.1016/j.imu.2019.100282.
[12] Dascalu, Avi & David, Eli. (2019). Skin cancer detection by deep learning and sound analysis algorithms: A prospective clinical study of an elementary dermoscope. EBioMedicine. 43. 10.1016/j.ebiom.2019.04.055.
[13] Chang, Hao. (2017). Skin cancer reorganization and classification with deep neural network.
[14] K. M. Hosny, M. A. Kassem and M. M. Foad, "Skin Cancer Classification using Deep Learning and Transfer Learning," 2018 9th Cairo International Biomedical Engineering Conference (CIBEC), Cairo, Egypt, 2018, pp. 90-93, doi: 10.1109/CIBEC.2018.8641762.
[15] Fujisawa, Yasuhiro & Inoue, Šae & Nakamura, Yoshiyuki. (2019). The Possibility of Deep Learning-Based, Computer-Aided Skin Tumor Classifiers. Frontiers in Medicine. 6. 191. 10.3389/fmed.2019.00191.